RCRA Facility Investigation
Task II Report
Pre-Investigation Evaluation of Corrective Measures Technologies
for
Naval Weapons Industrial Reserve Plant
Calverton, New York

Northern Division
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 0090

July 1993

Halliburton NUS
CORPORATION

RCRA FACILITY INVESTIGATION
TASK II REPORT
PRE-INVESTIGATION EVALUATION OF
CORRECTIVE MEASURES TECHNOLOGIES
FOR THE NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
CALVERTON, NEW YORK

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:

Northern Division

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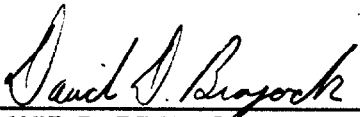10 Industrial Highway, Mail Stop #82

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Contract Number N62472-90-D-1298

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1.0 INTRODUCTION

1.1 AUTHORIZATION

As requested by the U.S. Navy, Halliburton NUS has prepared this Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Task 2 Report, Pre-Investigation Evaluation of Corrective Measures Technologies for the Naval Weapons Industrial Reserve Plant (NWIRP), located in Calverton, New York. This Task 2 Report is being prepared under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62472-90-D-1298, Contract Task Order (CTO) 0090. The Task 2 Report was prepared in accordance with the New York State RCRA Hazardous Waste Permit for the facility (NYSDEC 1-4730-00013/00001-0), dated March 25, 1992. This Task 2 Report is also intended to comply with the requirements of the United States Environmental Protection Agency (EPA) facility permit (EPA ID Number NYD003995198), dated May 11, 1992.

The Calverton NWIRP is located in Suffolk County on Long Island, New York, see Figures 1-1 and 1-2. The primary mission at the facility is to assemble and test aircraft. The NWIRP is a Government-Owned Contractor Operated (GOCO) facility operated by Grumman Corporation.

1.2 PURPOSE

This report has been prepared to aid in the development of a forthcoming Task 3 RFI Work Plan for the NWIRP. The purpose of the Task 2 Report is to identify potential corrective measure technologies and the corresponding field data to be collected during the Task 4 Facility Investigation (field activities). Technologies to be considered include on site or off site for the containment, treatment, remediation, and/or disposal of contamination. The data to be collected will be used to support the evaluation and selection of these technologies.

1.3 GENERAL FACILITY BACKGROUND

The Calverton NWIRP facility was constructed in the early 1950s for use in the development, assembly, testing, refitting, and retrofitting of Naval combat aircraft. Grumman Corporation has been the sole operator of the facility. Construction was completed in 1954. The facility supports aircraft design and production at the Grumman Bethpage, New York NWIRP.

CONNECTICUT

NWIRP
CALVERTON

LONG ISLAND SOUND

NEW
YORK
CITY

PECONIC BAY

ATLANTIC OCEAN

NEW
JERSEY

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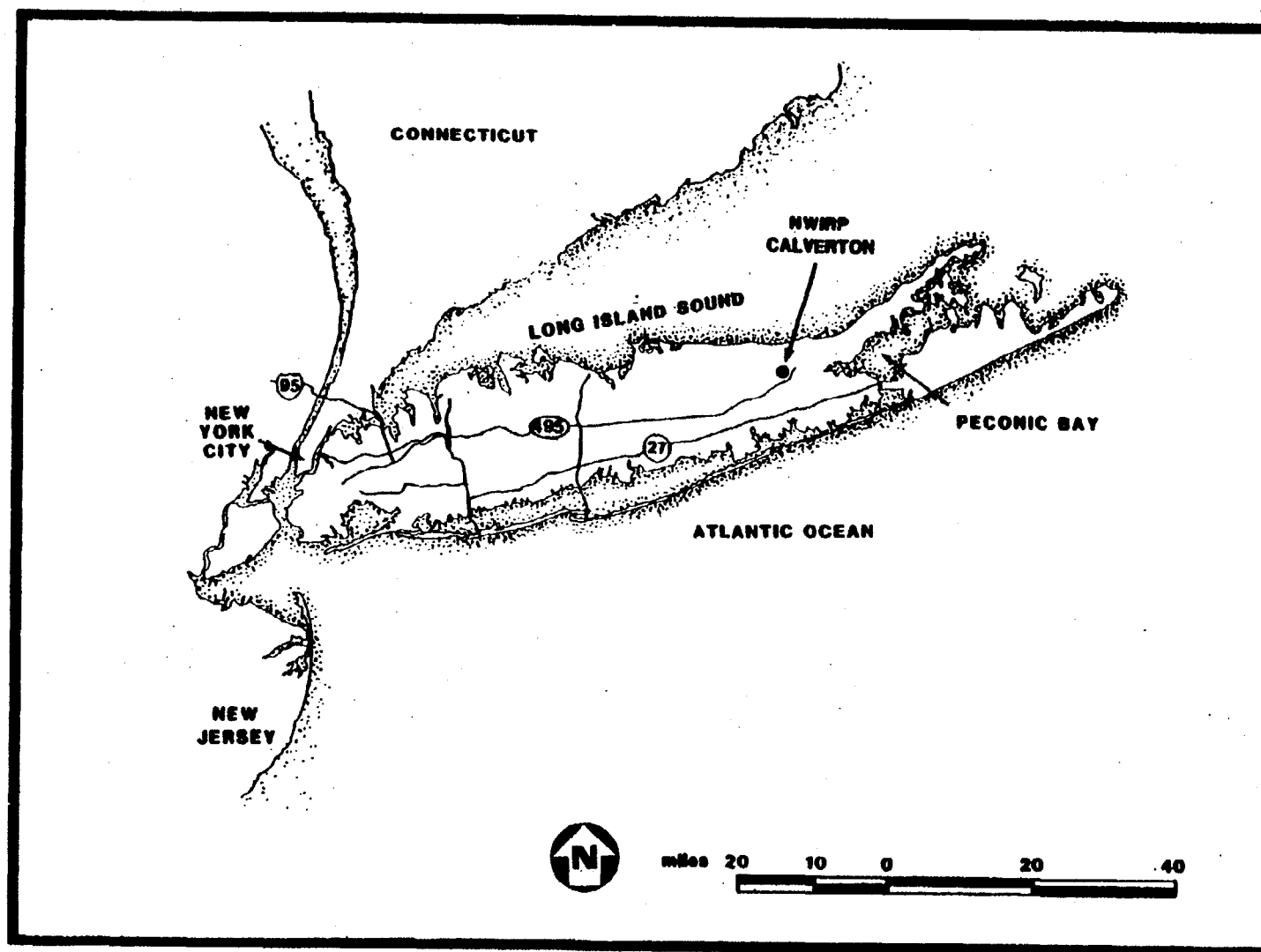
FIGURE 1-1

GENERAL LOCATION MAP

NWIRP, CALVERTON, NEW YORK

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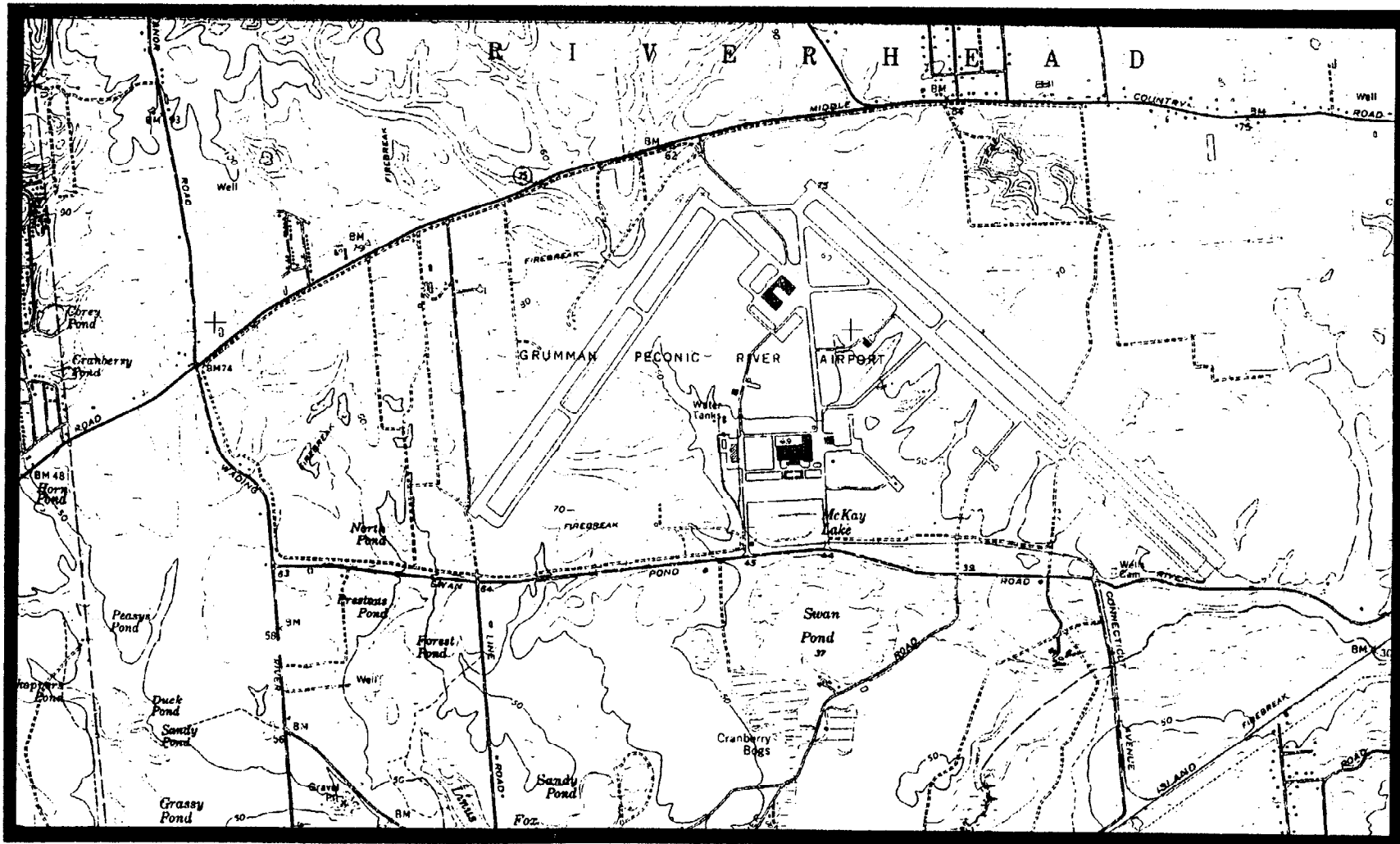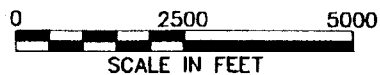
FIGURE 1-2

FACILITY LAYOUT MAP

NWIRP, CALVERTON, NEW YORK

0   2500   5000
SCALE IN FEET

HALLIBURTON NUS
Environmental Corporation

The majority of industrial activity at the facility is confined to the developed area in the center and south center of the facility, between the two runways. Industrial activities at the facility are related to the manufacture and assembly of aircraft and aircraft components. Hazardous waste generation at the facility is related to metal finishing processes, such as metal cleaning and electroplating. The painting of aircraft and components results in additional waste generation.

The areas of environmental concern are locations where industrial wastes were disposed, or where activities at the facility resulted in the deposition of hazardous materials to the soils of the facility. One of the disposal areas, namely the northeast pond area, was primarily used for the landfill disposal of nonhazardous materials. It is possible, however, that unknown hazardous materials may have been inadvertently placed in this area in the past. Since activities in the fire rescue training area involved the placement of fuels and solvents on the ground surface for ignition, it is possible that liquids did not fully combust but instead infiltrated the soil. The spillage of liquids such as fuels occurred in the fire training area as well as in the fuel depot and fuel calibrations area.

The four sites to be investigated under the Task 2 Report are summarized as follows.

- Site 1 - Northeast Pond Disposal Area (SWMU 1)
- Site 2 - Fire Training Area (SWMU 13)
- Site 6A - Fuel Calibration Area (AOC 1A)
- Site 7 - Fuel Depot

These sites were each investigated under a Site Investigation (SI) for the facility (Halliburton NUS, 1992), which found volatile organic, semivolatile organic, PCBs/pesticides and/or inorganic contamination at each of these sites.

Concurrent, but separate, activities are under way at other areas at the facility under a RCRA Facility Assessment Sampling Visit (RFA-SV). The purpose of the RFA-SV is to determine the potential for hazardous materials to present at other areas at the NWIRP, including cesspool/leach field areas, the coal pile area, and the ECM area.

1.4   REPORT ORGANIZATION

This report is divided into five sections. Section 1.0 is this brief introduction which summarizes the authority, purpose, and facility background. Section 2.0 provides a summary of the contaminated media and site background for each site. A discussion of potential corrective measure technologies is

presented in Section 3.0. Section 4.0 is a presentation of site-specific screening of technologies and Section 5.0 summarizes the general data requirements.

2.0 CONTAMINATED MEDIA OF POTENTIAL CONCERN

This section identifies the known or potential contaminated media at each site based on historical (site background) data and site investigation results. A summary of contamination at each site is also presented.

These sites were each investigated under a Site Investigation (SI) for the facility (Halliburton NUS, 1992), which found volatile organic, semivolatile organic, PCBs/pesticides and/or inorganic contamination at each of these sites.

2.1   SITE 1 - NORTHEAST POND DISPOSAL AREA

2.1.1   Site Background

Until 1984, the northeast pond disposal area was used primarily for the disposal of demolition debris such as concrete, brick, wood, and other construction materials. A final soil cover was placed over the disposed material in 1984. According to available information, other materials in the fill include aircraft sections and junked aircraft assembly tooling, office materials and furniture, pallets, and paint cans. The wreckage of several aircraft may be present in the area. Hazardous materials are not known to have been purposefully disposed of in the area. However, it is reported in the 1986 Initial Assessment Study (IAS) (RGH, 1986) that any of the following wastes may be present at the sites: petroleum, oils and lubricants (POLs), asphalt paving material, halogenated and nonhalogenated solvents, and paint sludges.

The waste materials were placed in a depression adjacent to the pond, and may have been used to fill portions of the pond. Soil borrowed from an adjacent hillside was used as cover material, creating a level area approximately 2 acres in size, with steep embankments up to 20 feet in height leading into the pond from the eastern edge of the disposal area.

No exposed wastes were observed on the surface or eastern embankment of the fill area during the SI. A small amount of debris, such as concrete chunks, wood scraps, and metal pieces, was exposed on the embankment leading into the woods from the south edge of the fill area. According to the IAS, approximately 7,500 cubic yards of material may have been disposed in this area.

2.1.2   Summary of Site Investigation Results

The contaminated media at this site are soils, surface water and sediments. Contaminants were detected in each of these media at concentrations exceeding background levels. Tables 2-1, 2-2, and 2-3 present the analytical results for the site soils, surface water, and sediment, respectively. Primary chemicals detected in the soil were toxic metals such as barium, cadmium, chromium, and lead with maximum concentrations of 3,320 mg/kg, 42.4 mg/kg, 959 mg/kg, and 314 mg/kg (estimated), respectively. Other chemicals were predominantly semivolatile aromatic compounds with a maximum concentration of 182,500 ug/kg. PCB isomers were tentatively identified among the semivolatile aromatic compounds. Volatile organic compounds were detected at low concentrations (<10 ug/kg). Table 2-1 provides a summary of analytical results for soils.

The surface water at the site was found to contain several inorganic chemicals at concentrations that exceed surface water quality criteria. Of these chemicals, chromium, copper, lead and cyanide were the most significant. Iron and aluminum were detected at elevated levels in the surface water at this site. Table 2-2 provides a summary of analytical results for surface water.

Chemicals detected in sediments consisted of chlorinated volatile organics at a maximum concentration of 2 μg/kg and chromium at a maximum concentration of 70.5 μg/kg. Copper and zinc were also detected in the sediments. Table 2-3 provides a summary of analytical results for the sediments at this site.

2.2   SITE 2 - FIRE TRAINING AREA

2.2.1   Site Background

The fire training area has been used by Grumman and Navy crash rescue crews as a training area since 1955, and possibly as early as 1952. According to the IAS, soil disturbances in the area were continuously evident in historical photographs. Before 1982, activities at the site consisted of clearing an area up to 100 feet or more in diameter and creating an earthen berm surrounding the area. The bermed area was then filled with a layer of water. Waste fuels, oils, and periodically, waste solvents were floated on the water and ignited. The IAS reports that up to 450 gallons of waste solvent were mixed with up to 2,100 gallons of waste fuel per year for use in the training exercises. Aircraft sections were sometimes placed in the area to simulate actual crash conditions. After 1975, waste solvents were reportedly no longer mixed with the material to be ignited; only waste fuel and oil was used. In 1982, the practice of using earthen berms was halted after the construction of a curbed, concrete pit approximately 50 feet in diameter.

TABLE 2-1

SUMMARY OF SOIL RESULTS
SITE1 - NORTHEAST POND DISPOSAL AREA
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit	No. of Detected Locations/ No. of Sample Locations		Range		Average of All Detected Concentrations	
		Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone
VOCs: CHLORINATED ALIPHATICS	(µg/kg)			(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)
1,2-Dichloroethane	5	2/4	0/4	1J-8J	--	4.33J	--
VOCs: NONCHLORINATED AROMATICS							
Toluene	5	2/4	0/4	1J-3J	--	2J	--
Ethylbenzene	5	1/4	0/4	2J	--	2J	--
SEMIVOLATILE ORGANIC COMPOUNDS							
Naphthalene	330	0/4	1/4	--	1,700J	--	1,700J
Dibenzofuran	330	0/4	1/4	--	1,600J	--	1,600J
Total PAHs	330	2/4	1/4	149J-760J	182,500J	480.5J	182,500J
Total Phthalates	330	3/4	0/4	35J-1,000	--	423.8	--
Total TIC PCBs		2/4	0/4	140-240	--	190	--
INORGANICS	(mg/kg)			(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Aluminum	40	0/4	1/4	--	22,400	--	22,400
Arsenic	2	2/4	0/4	5.5-31.7	--	17.6	--
Barium	40	3/4	1/4	48.3J-290J	3,320J	124.3J	3,320J
Cadmium	1	4/4	2/4	1.1-18.1	1.2-42.4	5.1	21.8
Chromium	2	4/4	1/4	23.8-959	73.1	174.6	73.1

TABLE 2-1
SUMMARY OF SOIL RESULTS
SITE1 - NORTHEAST POND DISPOSAL AREA
NWIRP CALVERTON, NEW YORK
PAGE TWO

Analyte	Quantitation/ Detection Limit	No. of Detected Locations/ No. of Sample Locations		Range		Average of All Detected Concentrations	
		Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone
INORGANICS (CONTINUED)	(mg/kg)			(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Copper	5	4/4	1/4	11.4J-184J	1,320J	85.8J	1,320J
Iron	20	1/4	0/4	15,100	--	15,100	--
Lead	0.6	3/4	1/4	19.9J-68.9J	314J	42.93J	314J
Manganese	3	1/4	0/4	482	--	482	--
Mercury	0.1	2/4	0/4	0.17-0.88	--	0.52	--
Nickel	8	3/4	1/4	9.9-118	233	44.63	233
Silver	2	3/4	1/4	2.2J-4.9J	115J	9.4J	115J
Vanadium	10	1/4	1/4	39.2J	85.2J	39.2J	85.2J
Zinc	4	3/4	1/4	81.5J-385J	2,830J	175.41J	2,830J
Cyanide	2	2/4	1/4	4.1-5.5	5.7	4.66	5.7

J   Estimated.
--   Below Background levels (inorganics) or below detection limits (organics)
TIC PCBs   PCBs isomers were tentatively identified in the semivolatile organic fraction.

TABLE 2-2

SUMMARY OF SURFACE WATER RESULTS
SITE 1 - NORTHEAST POND DISPOSAL AREA
NWIRP CALVERTON, NEW YORK

Inorganic Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/ No. of Samples	Range (µg/L)	Average of All Detected Concentrations (µg/L)	Federal AWQC
Aluminum	200	2/2	115-1,350	732.5	87
Chromium	10	1/2	63.3	63.3	11 (Hex) 210 (Tri)
Copper	25	1/2	14.9	14.9	12★
Iron	100	1/2	3,870	3,870	1,000
Lead	5	2/2	4.4-8.1	6.3	3.2★
Zinc	20	1/2	221J	221J	110★
Cyanide	10	2/2	12.5J-83.4J	47.95J	5.2

J   Estimated.
★   Hardness-dependent criterion; hardness assumed to be 100 mg/L.

TABLE 2-3

SUMMARY OF SEDIMENT RESULTS
SITE 1 - NORTHEAST POND DISPOSAL AREA
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit	No. of Detected Locations/No. of Sample Locations	Range	Average of All Detected Concentrations
VOCs: CHLORINATED ALIPHATICS	(µg/kg)		(µg/kg)	(µg/kg)
1,2-Dichloroethane	5	2/2	2	2
INORGANICS	(mg/kg)		(mg/kg)	(mg/kg)
Chromium	2	1/2	70.5	70.5
Copper	5	1/2	15.1	15.1
Zinc	4	1/2	58.9	58.9

Fire-fighting materials used in the exercises on site included aqueous fire-fighting foam (AFFF), gaseous Halon 1301, water, and dry chemical extinguishers (RGH, 1986).

A 6,000-gallon, underground storage tank located north of the fire training pit was used for an unknown time before 1982 to store waste fuels and solvents at the site. A spill of an unknown amount of liquid (less than 6,000 gallons) originated from this tank in August 1982. The spill reportedly occurred because a valve was left open (see Spill Reports in the SI). Marine Pollution Control (MPC) of Calverton, New York removed a total of 327 cubic yards of contaminated soil from the tank and spill areas in late August and early September 1982 as of result of the spill. Four groundwater monitoring wells were installed in the spill area in August 1982 (RGH, 1986; Halliburton NUS, 1992).

After the spill cleanup, a curbed, concrete, fire ring was constructed to prevent further soil contamination by waste fuels. A 1,000-gallon, above-ground fuel tank was installed to replace the 6,000-gallon tank (RGH, 1986). A second spill of approximately 300 gallons of waste No. 2 fuel oil occurred in 1983. The spill emanated from a leak in the piping leading from the 1,000-gallon tank. Seven additional monitoring wells were subsequently installed by MPC to monitor potential contamination related to the spills. By early 1987, a total of 12 wells were located in the area. MPC installed an additional 6 wells on November 23, 1987 (RGH, 1986; Halliburton NUS, 1992).

A groundwater recovery well was installed at the fire training area in December 1987. The system uses a groundwater pumping well and an oil recovery well (Halliburton NUS, 1992).

According to the IAS, hazardous materials expected to be associated with the fire training area include POLs; waste solvents such as toluene, methyl ethyl ketone, and lacquer thinner; and possibly soluble lead from fuels (RGH, 1986).

2.2.2   Summary of Site Investigation Results

The contaminated media at this site are soils and groundwater. Contaminants were detected in each of these media at concentrations exceeding background levels. Tables 2-4 and 2-5 present the results of analyses for site soils and groundwater, respectively.

The primary chemicals detected in the soils were nonchlorinated volatile organics with a maximum concentration of 15,000 ug/kg, and chlorinated volatile organics with a maximum concentration of

TABLE 2-4

SUMMARY OF SOIL RESULTS
SITE 2 - FIRE TRAINING AREA
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit	No. of Detected Locations/ No. of Sample Locations		Range		Average of All Detected Concentrations	
		Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone
VOCs: CHLORINATED ALIPHATICS	(µg/kg)				(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)
Chloroethane	10	0/5	1/5	--	230J	--	230J
1,1-Dichloroethane	5	0/5	1/5	--	6	--	6
1,1,1-Trichloroethane	5	0/5	1/5	--	3J	--	3J
Trichloroethene	5	1/5	0/5	4J	--	4J	-
Tetrachloroethene	5	2/5	1/5	4J-580	1J	199	1J
VOCs: NONCHLORINATED AROMATICS							
Ethylbenzene	5	1/5	1/5	12-1,600	350J	806	350J
Toluene	5	1/5	1/5	33J-4,300	770	2,166.5	770
Xylene	5	1/5	2/5	51-15,000	450-3,400	7,525.5	1,925
SEMIVOLATILE ORGANIC COMPOUNDS							
2-Methylnaphthalene	330	0/5	1/5	--	700J	--	700J
Total PAHs	330	3/5	1/5	391J-31,310J	28,540J	6,267.3J	28,540J
Total Phthalates	330	2/5	2/5	98J-340J	120J-270J	246J	195

TABLE 2-4
SUMMARY OF SOIL RESULTS
SITE 2 - FIRE TRAINING AREA
NWIRP CALVERTON, NEW YORK
PAGE TWO

Analyte	Quantitation/ Detection Limit	No. of Detected Locations/ No. of Sample Locations		Range		Average of All Detected Concentrations	
		Unsaturated Zone	Capillary / Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone
PCBs/PESTICIDES	(µg/kg)			(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)
Aroclor 1248	0.5	1/5	1/5	2,600-8,500	200	5,550	200
Aroclor 1260	1.0	3/5	2/5	21J-2,100	33J-1,600	744	816.5
Aldrin	0.05	1/5	--	36	--	36	--
4,4-DDE	0.1	3/5	--	7.5J-27	--	16.8	--
Endrin	0.05	1/5	1/5	14J	9J	14J	9J
B-BHC	--	1/5	--	18	--	18	--
INORGANICS	(mg/kg)			(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Antimony	12	1/5	--	13.2J	--	13.2J	--
Cadmium	1	1/5	--	1.7J	--	1.7J	--
Copper	5	1/5	--	5.3	--	5.3	--
Lead	0.6	2/5	--	35.7J-41.6J	--	38.7J	--
Zinc	4	1/5	--	43.9	--	43.9	--

J   Estimated.
--   Below background concentrations (for inorganics) or detection limits (for organics)

TABLE 2-5

SUMMARY OF GROUNDWATER RESULTS
SITE 2 - FIRE TRAINING AREA
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/ No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)
VOCs: CHLORINATED ALIPHATICS				
Chloroethane	10	1/6	4,500	4,500
1,1-Dichloroethane	5	5/6	4J-1,700	355.4
1,1,1-Trichloroethane	5	6/6	1J-130J	39.3
1,2-Dichloroethene	5	3/6	7-790	274
Trichloroethene	5	4/6	1J-10	5.3
Tetrachloroethene	5	3/6	1J-5J	2.7J
VOCs: NONCHLORINATED AROMATICS				
Toluene	5	3/6	2J-320J	126J
Ethylbenzene	5	2/6	10J-12	11
Xylenes	5	3/6	86-300J	133
VOCs: CHLORINATED AROMATICS				
1,2-Dichlorobenzene	10	1/6	74	74
SEMIVOLATILE ORGANIC COMPOUNDS				
Methylphenol	10	3/6	6J-73	30.3
Total PAHs	10	1/6	154J	154J
Total Phthalates	10	1/6	32J	32J
PESTICIDES				
4,4'-DDT	0.1	1/6	0.1J	0.1J
Aroclor 1260	1	3/6	0.83J-7.9	3.2

J   Estimated.

TABLE 2-5
SUMMARY OF GROUNDWATER RESULTS
SITE 2 - FIRE TRAINING AREA
NWIRP CALVERTON, NEW YORK
PAGE TWO

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/ No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)

INORGANICS

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/ No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)
Arsenic	10	5/6	4.4-40.7J	14.9
Barium	200	6/6	91.9-215	133
Beryllium	5	6/6	2-5.4	2.7
Cobalt	50	6/6	11.5-63J	31.7
Cadmium	5	5/6	3.5-22.8	11.1
Chromium	10	5/6	13.5-80.3	44.9
Copper	25	6/6	21-337	105.8
Lead	5	5/6	19-73.8	41.7
Iron	100	6/6	1,640-125,000	45,676.7
Magnesium	5,000	6/6	710-7,840	3,881.7
Manganese	15	6/6	97.5-2,680	678.4
Nickel	40	6/6	13.9-59.2	26.7
Vanadium	50	6/6	7.8-227	85.6
Zinc	20	2/6	179J-1,290J	734.5J
Cyanide	10	2/6	20-24.9J	22.5
Aluminum	200	6/6	5,490-80,200	28,366.7

J   Estimated

580 ug/kg. PCBs were detected at a maximum concentration of 8,500 ug/kg. Table 2-4 provides a summary of analytical results for the soils.

The primary organic compounds in the groundwater were chlorinated volatile organics with a maximum concentration of 4,500 ug/L. Lower concentrations of other chlorinated and nonchlorinated volatile organics were also detected. Cadmium, chromium, copper, lead and cyanide were detected at maximum concentrations of 22.8 ug/L, 80.3 ug/L, 337 ug/L, 73.8 ug/L and 24.9 ug/L, respectively. Table 2-5 provides a summary of analytical results for groundwater.

2.3   SITE 6A - FUEL CALIBRATION AREA

2.3.1   Site Background

The fuel calibration area has been active since the construction of the facility in the early 1950s. The area has moved slightly over the years; the original fuel calibration area is approximately 250 feet southwest of the present area. The focus of activity in the present area shifted from the southern to the eastern edge of the concrete pad at an unknown time.

According to the IAS, periodic spills of jet fuels, including JP-4 and JP-5, have occurred throughout the operation, mostly due to small fuel system leaks or accidental spillage during refueling. Much of this material was spilled to the concrete surface; however, small amounts may have reached the surrounding soil. Over 230 gallons of fuel are known to have spilled in this area during the 1980s. The majority of spilled fuel and contaminated soil was reportedly cleaned up.

At the time of the site inspection, little evidence of fuel spillage was present at any of the fuel calibration-related areas. Stressed vegetation was present in the area adjacent to the southern edge of the fuel calibration pad, in the area beneath the old fuel piping and manifolds.

The eastern edge of the concrete pad is currently used for fuel calibration activities. The southern edge of the pad was formerly used for the same activity; a shed, piping, and fuel filtering devices are still located in the area.

Eighteen monitoring wells were placed south and southeast of the fuel calibration pad by MPC between March 1984 and November 1987. A groundwater recovery unit including a pumping well and an oil recovery well was installed in 1987. The tank is connected to a pipe that follows the drainage ditch paralleling the southern edge of the calibration pad. The ditch enters a buried culvert southeast of the pad and eventually discharges to a small pond 1,500 feet south of the calibration

pad. The recovery system pipe ends in the underground culvert. Red iron staining was observed during the site investigation in the ditch adjacent to the oil/water tank separation outfall and at the end of the culvert. The staining in the ditch near the oil/water separator reportedly resulted from a break in the piping early in 1990 (RGH, 1986; Halliburton NUS, 1992).

2.3.2   Summary of Site Investigation Results

The contaminated media at this site are soils, groundwater and sediments. Contaminants were detected in each of these media at concentrations exceeding background levels. Tables 2-6, 2-7, and 2-8 present the results of soil, groundwater, and sediment analyses, respectively.

The primary chemicals detected in the site soils were fuel-related nonchlorinated volatile organic compounds, with a maximum concentration of 17,000 ug/kg, and 1,1,1-TCA, with a maximum concentration of 7,400 ug/kg. Table 2-6 provides a summary of analyses for the soils.

Both organic and inorganic chemicals were detected at significant concentrations in the site groundwaters. The primary organic chemicals in the groundwater were chlorinated and nonchlorinated volatile organics with a maximum concentration of 2,600 ug/L and 370 ug/L, respectively. The inorganic contaminant was lead with a maximum concentration of 1,740 ug/L. Table 2-7 provides a summary of analytical results for the groundwater.

Sediment contaminants in the ditch at the fuel calibration site were methylene chloride at 1 μg/kg, polynuclear aromatic hydrocarbons at a maximum concentration of 1,470 μg/kg, and lead at 71.3 mg/kg. Table 2-8 summarizes the analytical results for the sediments.

2.4   SITE 7 - FUEL DEPOT AREA

2.4.1   Site Background

The fuel depot area was constructed in the early 1950s and has been active since that time. The depot consists of two areas of underground fuel and oil storage tanks. The UST areas are primarily soil covered, with scattered concrete pads surrounding fill and vent pipes. A concrete parking area for fuel tank trucks is immediately south of the UST areas. A pumphouse and truck filling bay are situated west of the UST areas.

Monitoring wells are located both within the fuel depot area and in the surrounding areas. A total of 34 monitoring wells are located in the area (RGH, 1986; Halliburton NUS, 1992).

TABLE 2-6

SUMMARY OF SOIL RESULTS
SITE 6A - FUEL CALIBRATION AREA
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit	No. of Detected Locations/ No. of Sample Locations		Range		Average of All Detected Concentrations	
		Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone
VOCs: CHLORINATED ALIPHATICS	(µg/kg)				(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)
Methylene Chloride	5	2/7	0/2	1J	--	1J	--
1,1,1-Trichloroethane	5	1/7	0/2	7,400J	--	7,400J	--
VOCs: NONCHLORINATED AROMATICS							
Toluene	5	2/7	0/2	7J-1,300J	--	653.5J	--
Ethylbenzene	5	2/7	0/2	130-2,700J	--	1,610	--
Xylene	5	2/7	0/2	700-17,000J	--	8,850	
SEMIVOLATILE AROMATICS							
Naphthalene	330	2/7	0/2	120J-3,100	--	1,540	--
Dibenzofuran	330	1/7	0/2	380J	--	380J	--
Total PAHs	330	1/7	0/2	400J	--	400J	--
INORGANICS	(mg/kg)			(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Lead	0.6	1/7	0/2	21.2J		21.2J	--

J Estimated.
-- Below Background concentration (inorganics) or below detection limits (organics).

TABLE 2-7

SUMMARY OF GROUNDWATER RESULTS
SITE 6A - FUEL CALIBRATION AREA
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/ No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)

VOCs: CHLORINATED ALIPHATICS

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/ No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)
Chloroethane	10	1/6	2,600	2,600
1,1-Dichloroethane	5	4/6	3J-300	82
1,1,1-Trichloroethane	5	3/6	4J-23	12
1,1-Dichloroethene	5	1/6	27	27
Trichloroethene	5	1/6	3J	3J

VOCs: NONCHLORINATED AROMATICS

Analyte				
Benzene	5	1/6	4J	4J
Toluene	5	1/6	140	140
Ethylbenzene	5	2/6	32-68	50
Xylene	5	2/6	290J-450	370

VOCs: CHLORINATED AROMATICS

Analyte				
1,2-Dichlorobenzene	10	1/6	3J	3J

SEMIVOLATILE ORGANIC COMPOUNDS

Analyte				
Total PAHs	10	2/6	145-10,300J	5,223
Total Phthalates	10	5/6*	2J-380	78.4

INORGANICS

Analyte				
Lead	3	6/6	33.5-1,740	340

*   Phthalates are common laboratory contaminants.
J   Estimated.

TABLE 2-8

SUMMARY OF SEDIMENT RESULTS
SITE 6A - FUEL CALIBRATION AREA
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit	No. of Detects/ No. of Samples	Range of Detected Concentrations	Average of All Detected Concentration
ORGANICS	(µg/kg)		(µg/kg)	(µg/kg)
Methylene Chloride	5	1/3	1J	1J
Total PAHs	330	2/3	47J-1,470J	759
INORGANICS	(mg/kg)		(mg/kg)	(mg/kg)
Lead	3	1/3	71.3J	71.3J

J   Estimated.

A garage and paved parking area for trucks and equipment used by the Grumman transportation department are located north of the fuel depot. Areas to the east and south are wooded. A paved roadway leading from the south gate is adjacent to the depot to the west; a storage building and the fuel system laboratory building are located west of the road (USGS, 1967; RGH, 1986).

The fuel depot area is used for the storage and distribution of fuel products, such as JP-4 and JP-5 jet fuel at the facility. Fuels are stored in underground storage tanks. The material is then transferred to trucks for use in the flight preparation areas of the facility. These activities have resulted in groundwater contamination by fuels, which may have occurred by tank and pipe leakage, overfilling, and spills (RGH, 1986; Halliburton NUS, 1992).

2.4.2   Summary of Site Investigation Results

The contaminated media at this site are soils and groundwater. Contaminants were detected in each of these media at concentrations exceeding background levels.

The primary chemicals detected in site soils were PAHs at a maximum concentration of 4,750 ug/kg. Table 2-9 provides a summary of analytical results for soils.

Both organic and inorganic chemicals were detected in site groundwater at significant concentrations. The primary organic chemicals in the groundwater were the fuel-related nonchlorinated volatile organics at a maximum concentration of 960 ug/L. The primary inorganic chemical was lead with a maximum concentration of 692 ug/L. Table 2-10 provides a summary of analytical results for the groundwater.

TABLE 2-9

SUMMARY OF SOIL RESULTS
SITE 7 - FUEL DEPOT SITE
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit	No. of Detected Locations/ No. of Sample Locations		Range		Average of All Detected Concentrations	
		Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone	Unsaturated Zone	Capillary/ Saturated Zone
VOCs: CHLORINATED ALIPHATICS	(µg/kg)			(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)
1,2-Dichloroethane	5	1/3	1/3	1J	5	1J	5
SEMIVOLATILE AROMATICS							
Total PAHs	330	2/3	0/3	322-4,750	--	2,536	--

J   Estimated.
--   Less than detection limits.

TABLE 2-10

SUMMARY OF GROUNDWATER RESULTS
SITE 7 - FUEL DEPOT SITE
NWIRP CALVERTON, NEW YORK

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)

VOCs: CHLORINATED ALIPHATICS

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)
1,1,1-Trichloroethane	5	1/7	1J	1J

VOCs: NONCHLORINATED AROMATICS

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)
Benzene	5	2/7	14-390	202
Toluene	5	4/7	2-540	171.3
Ethylbenzene	5	4/7	5-120	77.3
Xylene	5	5/7	10-960	343.4

SEMIVOLATILE ORGANIC COMPOUNDS

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)
Total PAHs	10	1/7	86J	86J
Total Phthalates	10	2/7	5-72	38.5

INORGANICS

Analyte	Quantitation/ Detection Limit (µg/L)	No. of Detects/No. of Samples	Range of Detected Concentrations (µg/L)	Average of All Detected Concentration (µg/L)
Lead	3	7/7	11.8-692	120.5

J   Estimated.

3.0 POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES

This section presents a brief description of potential corrective measure technologies for the remediation of soil/sediments and groundwater/surface water. The following is a list of technologies considered for wastes/soils/sediments remediation:

- Capping
- Excavation/dredging
- In-situ soil washing
- In-situ air sparging and vapor extraction/bioventing
- In-situ vitrification
- In-situ radio frequency heating
- Soil washing/solvent extraction
- Thermal treatment
- Solidification/stabilization
- Biological treatment
- Chemical dechlorination
- Offsite/onsite landfill disposal

The following is a list of technologies considered for groundwater/surface water remediation:

- Hydrodynamic controls/subsurface barriers
- Extraction wells/subsurface drains
- In-situ air sparging
- In-situ biological treatment
- Non aqueous-phase liquid removal
- Air/steam stripping
- Activated carbon adsorption
- Enhanced oxidation
- Precipitation/suspended solids removal
- Ion exchange
- Ultra filtration/reverse osmosis
- Biological treatment
- Offsite/onsite disposal

3.1 CONTAMINATED WASTES/SOILS/SEDIMENTS

3.1.1 No Action

No action is considered a potential measure for SWMUs that have not experienced any releases of hazardous substances or certain SWMUs that have been determined to have minimal short-term or long-term effect on soils, air, groundwater or surface water quality. No action might be accompanied with a groundwater monitoring or a leachate collection system to detect any future releases from a closed SWMU or adjoining areas.

No action will allow any contamination present to remain at the facility within the existing SWMU. Rainwater infiltration might continue at some units. Candidate no action units would be evaluated on a unit-by-unit basis.

The negligible costs associated with no action measures for source areas must be weighed against the additional costs for operation of a groundwater corrective action that may have to handle any projected future releases from the no action units. These economic evaluations will be performed as part of the detailed Corrective Measures Study.

3.1.2 Containment

3.1.2.1 Capping

Capping technologies are used to minimize rainfall percolation and waste leaching, to reduce migration of exposed waste materials, and to minimize the potential for direct contact with contaminants. Capping can involve the installation of an impermeable barrier or compacted soil layer over the wastes and can include an overlying layer of topsoil and vegetative cover to protect the cap. Excavation, grading, and/or removal of some of the waste material in preparation for capping is often required.

Cap designs are not specified for RCRA Corrective Actions under 40 CFR 264.101; however, the primary purpose of any type of cap is to reduce contaminant releases to groundwater. RCRA closure requirements for regulated surface impoundments under 40 CFR 264.228 provide performance specifications for caps as follows:

- Provide long-term minimization of the migration of liquids through the closed impoundment.

- Function with minimum maintenance.

- Promote drainage and minimize erosion or abrasion of the final cover.

- Accommodate settling and subsidence so that the cover's integrity is maintained.

- Have a permeability less than or equal to the permeability of any bottom liner or natural subsoils present.

Although the RCRA closure regulations are not applicable to corrective actions, these cap specifications provide a useful reference for the functional design of a SWMU cap.

Possible capping materials include the following:

- Synthetic membranes
- Cement/asphalt
- Clay
- Amended soil
- Multi-media (combination)

Synthetic membranes such as high density polyethylene (HDPE), polyvinyl chloride (PVC), and Hypalon® have been used extensively as capping materials with positive, reliable results. Some synthetic materials may require covering to prevent degradation by ultraviolet light. Cement and asphalt have also been used as capping materials; however, these materials are subject to cracking and deterioration and are not reliable over the long term (>10 years).

Clay caps can provide an economical, low permeability cover over the long term if a suitable clay is used and the cap is properly constructed. The availability of local clay borrow areas must be determined, and the clay should have an adequate plasticity to achieve a permeability of $<10^{-7}$ centimeters per second at a normal compactive effort.

Compacted soil caps are similar to clay caps, except that a soil cap would be more permeable than a clay cap. A soil cap is primarily a means of covering exposed wastes, in addition to reducing infiltration rates and reducing offsite transport of hazardous substances. The use of soil additives

may be applicable to reduce permeability. Soil additives (such as bentonite) are effective in cases where clean soils are abundant but too permeable for use as capping materials.

Capping isolates wastes from contact with the atmosphere and with the facility personnel. Capping will protect human health by reducing the potential for direct contact with contaminated materials. It will also reduce or eliminate the potential for offsite migration of contaminated materials via surface water runoff and subsequent transport.

Other considerations for capping include the long-term settlement potential of the subsurface materials and the local availability of suitable soils, if soil caps are considered.

The need for capping measures at any particular SWMU will be based on the results of the RFI and risk assessment, and the economic evaluations performed during the Corrective Measures Study. The costs associated with capping one or more units will be weighted against the expected benefits from reduced contaminant releases to groundwater and subsequent reduced groundwater remediation costs.

Containment of migration of contaminants from sediments cannot be accomplished by capping. Placement of a layer of clean sand/gravel can reduce the release of contaminants into the surface water.

3.1.3   Removal

Contaminated soils/sediments may be removed for further treatment/disposal, when in-situ remediation is not applicable. Technologies that may be potentially considered for the removal of soils is discussed under excavation. Technologies that are more commonly applicable to the removal of sediments are discussed under dredging.

3.1.3.1   Excavation

Excavation consists of two main activities: (1) Casting and Loading, and (2) Hauling. The main categories of excavation machinery are backhoes, cranes and attachments, and dozers/loaders.

Backhoes consist of a crawler-mounted boom or dipper stick with a hoe dipper attached to the outer end. The hoe dipper is a toothed bucket, whose orientation is controlled by a drag cable. The relative motions between the hoe dipper, the dipper stick and boom are all hydraulically controlled. The typical maximum depth of excavation of backhoes is 30 feet. Deeper depths of excavation from the

surface can be achieved by using extended dipper sticks, modified engines, and counterweight frames (EPA, 1985). Alternatively, a "terraced" or "working-bench" approach can be used to excavate beyond the maximum reach of the dipper stick, in which the backhoe can descend by means of a ramp that is excavated on the walls of the pit.

Cranes equipped with clamshells or an orange-peel buckets are commonly used for large-scale rehandling/staging of excavated materials or for large-scale drum excavation using drum grapples. Clamshells consist of a two-jawed bucket that is used to grab the soil which is then hoisted onto a hauler or into a staging area. Cranes equipped with a drag bucket connected by cable to the boom can be used for excavating large areas of land with loosely compacted soil. Although similar to the clamshell in design, the drag bucket loads soil by pulling the soil towards the crane rather than grabbing. Subsurface excavation for depths of up to 30 feet can be achieved with drag lines. However, excavation with draglines at landfill sites containing explosive materials or very toxic chemicals is unsafe.

Dozers and loaders are equipped with blades and bucket lifts respectively, and are suitable for crawler- or tracter-mounting. Crawlers can be used for excavating over rough, unstable surfaces, whereas tractors are more suited for rough, muddy and sloping terrain. Dozers and loaders are usually used in combination with deep excavation equipment such as backhoes for earth-moving and staging applications. Dozers are very useful in earth grading and moving earth/undamaged or empty drums to a more suitable location for loading. Loaders are are widely used in hauling and staging undamaged drums.

Hauling consists mainly of earth-moving using scrapers and trucks. Scrapers are used in removing and hauling surface cover materials and respreading/compacting cover soils. Scrapers are more suited to soft- to medium-density cover soils. Push-loaded (tractor-driven) machines must be used for medium to hard rock and earth. Scrapers are not suitable at sites where drums are buried near the surface.

Haul trucks are large, rubber-tired vehicles with capacities of 1 to 100 tons depending on the number of trailers and axles. Smaller 1- to 2-ton haul trucks are used for drum transportation.

Background knowledge on the type of disposal or waste placement practices (presence of bulk debris, drums, etc.) is necessary to determine the type of excavation equipment that may be applicable to a site. The extent of contamination would be necessary to determine the depth of excavation required and consequently, the type of equipment that would be suitable.

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Vertical and horizontal extent of contamination.
- Background information on waste disposal practices.
    -Presence of drums, bulk debris, etc.

3.1.3.2 Dredging

Removal of contaminated sediments would be necessary to enable the application of soil remediation technologies for treatment.

Sediment removal is normally called "dredging." The dredged sediments must be partially or completely dewatered prior to treatment. Three general types of dredges are available for sediment removal: mechanical, hydraulic, and pneumatic.

Mechanical Dredging

Mechanical dredging equipment are similar to those of excavation. Both land-based as well as pontoon/barge-mounted equipment are available for dredging operations. Sediment resuspension and material loss is high during mechanical dredging. Clamshells, draglines, backhoes, and bucket ladder dredges are available equipment for dredging. Clamshells, draglines and backhoes are similar to those described in the previous section for excavation.

Bucket ladder dredges consist of an inclined submersible ladder which supports a continuous chain of buckets that rotate about a pivot at the point of attachment to the ladder. As the chain rotates around the ladder, the buckets excavate sediments at the bottom end and unload at the top end of the ladder. The production rate of bucket ladders is more than those of the other equipment, but resuspension and sediment loss is also greater.

Hydraulic Dredging

Hydraulic dredging consist of the use of centrifugal pumps to remove and transport sediments in a slurry form. The sediments are pumped to the surface for dewatering and/or further treatment. The suction end is mounted on a movable ladder which can be raised or lowered to a specific dredging depth.

The plain suction dredge relies entirely on the pump for dislodging the sediments and transportation. The plain suction dredge can be used for the removal of free sands, gravel, and other unconsolidated material. The dustpan dredge has a widely flared head with high-pressure water jets that are mounted along the head. The dustpan head captures material dislodged by the jets while the pump removes the material. The cutterhead dredge has a rotary-cutter apparatus attached to the suction end. The cutter breaks and dislodges all types of alluvial consolidated material as well as compacted deposits such as clay and glacial till.

Pneumatic Dredges

Pneumatic dredges use air-operated pumps to remove sediments. These dredges require a minimum of 7.5 feet of water depth for efficient operation of the compressed air cylinders. Pneumatic dredges yield denser slurries and less sediment resuspension than conventional hydraulic dredges, however, the production rates are less. Depending on the mode of application of the compressed air, pneumatic dredges are classified as airlift, pneuma, and oozer type, with the oozer type offering the highest slurry concentration and least resuspension of sediments.

As indicated above, mechanical, hydraulic, and pneumatic dredges offer various advantages compared to each other, and also have certain limitations to their relative effectiveness. Typically, the physical nature/geological characteristics of the sediments, the thickness of contaminated sediments and concern for resuspension are important factors in deciding the type of dredging equipment suitable for the application. Also, the depth of water may pose limitations on the effectiveness of certain dredging equipment.

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Vertical and horizontal extent of contamination.
- Physical characteristics of sediment.

3.1.4   In-Situ Treatment

All technologies discussed in this section are performed in situ. The contaminated soils are treated in place by various physical/chemical/biological treatment technologies or combinations thereof. These technologies cannot be readily applied to sediment treatment.

3.1.4.1 In-Situ Soil Washing

Organic and inorganic contaminants can be washed from contaminated soils by means of extraction processes (EPA, 1985a). Water or an aqueous solution can be injected into the area of contamination or the area can be flooded with the solution. The contaminated elutriate is collected for removal and disposal or onsite treatment and reinjection. During elutriation, sorbed contaminants are mobilized into solution because of their solubility, formation of an emulsion, or by chemical reaction with the flushing solution. Collection of the elutriate is required to prevent uncontrolled migration through uncontaminated soil or into groundwater or surface water (EPA, 1986a; CDM, 1985b; EPA 1984a). In-situ treatment is typically applied when soil has a hydraulic conductivity greater than 1×10^{-4} cm/sec (Nash and Traver, 1986).

In-situ soil washing typically uses a system of extraction and injection wells. The extracted groundwater is treated by normal groundwater technologies, such as air stripping, biodegradation, activated carbon adsorption, chemical precipitation, etc. The treated groundwater is reinjected into the subsurface to begin another cycle of washing/extraction/treatment, thus progressively reducing the concentrations of contaminants in the soils.

The removal of gross organic contaminants from the soils such as free product would require the use of solubilizers/emulsifiers or surfactants. Such applications are limited in practice because of the concern for dispersing contaminants in the event of inadequate capture by extraction and also because of the necessity to address the removal of the additives.

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Contaminant nature.
- Geology/hydrogeology.
- Soil organic fraction/partition coefficient.

3.1.4.2 In-situ Air Sparging and Vapor Extraction/Bioventing

Hydrocarbon contamination consisting of fuel and solvent constituents often are found partitioned into different media. These hydrocarbons may be adsorbed onto soil particles in the unsaturated and saturated zones, be present dissolved in the pore water, or be present as a separate organic layer (free product) (EPA, March 1990). Consequently a combination of technologies must be employed for

cleaning up the soils and groundwater. One such combination of innovative in-situ technologies is air sparging and vapor extraction/bioventing.

In-situ air sparging consists of injection of contaminant-free air into the saturated zone within the contaminated plume. The injected air bubbles disperse within the saturated zone and contact the contaminants. In this process, the VOCs adsorbed on the soil particles and dissolved in the water are volatilized, like an in-situ air stripping process. The VOCs are then carried into the vadose zone by the air phase, within the radius of influence of an operating vapor extraction system (Marley et al., 1992).

Vapor extraction is a widely used technology for the remediation of unsaturated zone soils. This technology consists of the application of vacuum in the subsurface for the removal of volatilized contaminants. The vacuum is applied to the subsurface using extraction wells with a permeable packing. The wells are normally deep enough to penetrate the unsaturated zone completely until the capillary fringe. Vacuum is created by the use of vacuum pumps at the mouth of the extraction well. This vacuum induces an air flow in the unsaturated zone, which carries the volatilized contaminants within the radius of influence of the extraction wells to the surface for further treatment (Hutzler et al., 1989). Air permeability tests are required at a pilot-scale to determine whether adequate transport of air and vapors can be achieved by sparging and vacuum extraction.

Air sparging and vapor extraction are primarily aimed at the removal of VOCs from the soils and groundwater. However, petroleum fractions (especially jet fuel) typically contain semi-VOCs to a significant extent which cannot be directly removed by these methods. These semi-VOCs can be biodegraded using native aerobic microbes in the soil, by providing a suitable environment for their activity. Such a variation of in-situ biodegradation is called bioventing. In bioventing, the supply of oxygen is assumed to be more limiting for adequate microbial activity than normal levels of pH, temperature, moisture and nutrients/micronutrients present in most soils. Therefore by supplying oxygen to the subsurface using air sparging, the activity of aerobic microbes can be enhanced and can result in the removal of semi-VOCs. The presence of a viable microbial population is an important criterion. Also, depending on the necessity, nutrients may also be introduced periodically to sustain the microbial population. The biodegradation products of petroleum are carbon dioxide and water, which are removed by the vapor extraction system along with the VOCs from the soils and groundwater.

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Presence of volatile organic contaminants, indication of biodegradation, etc. in the soil-gas.
- Air conductivity.
- Biodegradability (measured by oxygen demand for oxidation), nutrients (nitrogen, phosphorus), micronutrients (trace metals, salts, sulfur).

3.1.4.3   In-Situ Vitrification

In-situ vitrification consists of melting the contaminated material and subsequently cooling and solidifying it into an impermeable, stable mass. In-situ vitrification provides a high degree of containment (Smith, 1985). Energy is applied through electrodes inserted around the area to be melted. Temperatures up to 3,000°F (1,649°C) may be required to melt most natural soils and rocks. The electrodes are placed into the ground by drilling or other appropriate methods. Then graphite, in contact with the waste material, is connected across the electrodes to act as a "starter" in melting the waste (Smith, 1985; Truett, 1982). The molten zone grows downward as the energy is applied, encompassing the contaminated material and producing a vitreous mass. Convective currents distribute the contaminants uniformly within the melt. When the power is turned off, the molten material begins to cool. The final product is a glass-like material resembling natural obsidian. Any subsidence due to volume reduction can be backfilled to original grade (Fitzpatrick, 1984). The technology has been developed by Battelle Pacific Northwest Laboratory.

This technology may be applicable to organic wastes, including halogenated organics (Camp Dresser & McKee, 1985a; Smith, 1985). Organics and cyanide are volatilized/destroyed by the processes (Arthur D. Little, 1986).

In-situ vitrification can be performed without close contact between the workers and the waste (Smith, 1985). Most organics will decompose, and metals will fuse or vaporize. The gases and vapors are collected and will require further treatment, such as scrubbers or filters. This will create secondary liquid and/or solid residuals for disposal (EPA, 1982; Smith, 1985). There may also be lateral gas movement when volatiles are present in the waste. The optimum depth for the use of this process is 12 to 20 feet.

The implementation of this process may require additional pollution controls to accommodate any volatiles that may be emitted. A limited amount of equipment is currently available. A groundwater

cutoff system may be needed upgradient to prevent inflow to the site while the system is operating. Presence of containerized organic/aqueous wastes could be a potential hazard to the implementation of this technology. Metal objects could cause an electrical hazard due to short circuiting.

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Depth to groundwater and rainfall potential.
- Background information on waste disposal practices.
  - Presence of drums, bulk metal debris, etc.

3.1.4.4   In-Situ Radio Frequency Heating

In in-situ radio frequency heating, the energy required to heat contaminated soils is provided by radio frequency (RF) generators operating between 2 and 45 megaHertz. In this frequency range, dipolar molecules absorb electromagnetic (EM) energy, which causes them to vibrate and rotate and thereby convert the EM energy to heat. RF energy is transmitted to the ground via electrodes placed horizontally above the soil surface. The area underlying the electrodes is gradually heated to temperatures of up to 750°F (399°C) at depths of up to 33 feet. The penetration depth of EM energy is inversely related to frequency and soil conductivity; thus, by varying the frequency, the depth of penetration can be adjusted to meet site-specific requirements [IIT, 1988]. As in a domestic microwave oven, the presence of metal objects would interfere with the transmission of the electromagnetic waves.

As the temperature in the soil increases, waste constituents are removed by several mechanisms. Energy absorption in the soil causes a phase-change interface (equivalent to the boiling point of water) to migrate downward through the ground. Above the interface, low boiling hydrocarbons are either volatilized or stripped from the soil by rising steam. Once the interface reaches the bottom of the contamination zone, further removal of organic contaminants progresses by vaporization or pyrolysis (IIT, 1988).

Vapors and gases containing contaminants escape toward the soil surface and are collected in a vapor barrier, which consists of a prefabricated metal or air-inflatable structure. In a typical installation, the structure would enclose ten rows of copper-clad, steel pipe electrodes per acre, with each row being 209 feet long. The vapor barrier system collects both gases and liquid condensate for transport to a treatment system. The treatment scheme will vary, depending on the type of wastes treated. RF radiation emitted upward by the electrodes is grounded by a wire mesh surface (IIT, 1988).

Containerized wastes may pose a potential hazard because of wave interference and exploding vapors.

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Depth to groundwater and rainfall potential.
- Background information on waste disposal practices.
    - Presence of drums, bulk metal debris, etc.

3.1.5   Ex-Situ Treatment

These technologies are applicable to soils/sediments after excavation/dredging.

3.1.5.1 Soil Washing/Solvent Extraction

Soil washing (using water) and extraction (using solvents and surfactants) processes that are conducted on excavated soils/sediments for removal of contaminants and separation of cleaned soil/sediment particles.

Contaminants adsorbed on the solid particles of a soil matrix can conceivably be removed or separated from the soil through the use of extraction processes. The economic feasibility and success of such extraction technologies are dependent upon the properties of the contaminants, the characteristics of the solid matrix, the extraction method, and the unit-specific environmental concerns.

Contaminants adsorbed on a soil or sludge matrix can be desorbed through the application of hydraulic forces and physiochemical reaction. The passage of water through the soil or sludge can scrub and/or dissolve the water-soluble contaminants and entrain these dissolved contaminants in the water. For those contaminants that are hydrophobic in nature, solubility can be enhanced through the use of aqueous surfactants. These extractants desorb contaminants from a solid matrix through the modification of the surface tension of the interstitial aqueous solution. The consequent increase of the surface of contact between the contaminant and the solution can improve the separation of the contaminant from the solid particles. A specific solvent can also be used in place of water. Processes such as ion exchange, oxidation reduction, complexation, and desorption can be involved, depending on the selected solvent. Other mechanisms, such as the control of solvent properties

through temperature changes and the application of gas stripping, etc., can also be used to remove contaminants from the soil matrix.

The contaminant entrained in the carrier fluid/gas (water, solvent, or air) should be removed from the interstitial pore area. The ease of removal of the carrier fluid from the soil or the clogging of pore spaces may significantly affect the application of extraction technologies. The removed carrier fluid containing the extracted contaminant can be treated for reuse.

Solvent extraction and soil washing are methods for leaching of organic and inorganic pollutants from the soil (Erdogan and Sadat, 1984). Soil may be excavated prior to treatment or may be treated in situ. For post-excavation applications, the contaminated soil is mixed with an extracting agent (solvent or water) to transfer the contaminants from the solid to the liquid phase. The mixing step occurs in a stirred reactor. It is possible to remove not only the solvent-soluble or water-soluble contaminants, but also insoluble contaminants that may form a stable colloidal suspension (EPA, 1986a; Rulkens et al., 1985). After extraction is complete, the treated soil particles are separated from the extracting agent via sedimentation and filtration.

Specific solvents have been developed to extract certain classes of organic chemicals, such as halogenated compounds (Peterson, 1986). Extraction of other types of contaminants, such as heavy metals, has been tested on the laboratory scale (Ellis et al., 1978). Triethylamine and hexane are commonly used solvents that may be effective and are biodegradable. Triethylamine (TEA) is used for the patented Basic Extractive Sludge Treatment (BEST) process that is commercially available through Resources Conservation Company. The process can be used to treat wastes from petroleum refineries, wastewater treatment systems, and other facilities that generate hazardous wastes and/or difficult to handle sludges, soils, and sediments. TEA acts as an effective solvent for both oil soluble and water soluble compounds.

Specific contaminant removal depends on the selection of an appropriate solvent. Results from various studies (EPA, 1986a; Erdogan and Sadat, 1984; Rulkens et al., 1985) indicate that the following contaminants can be removed via solvent extraction:

- Heavy metals, such as cadmium, zinc, copper, nickel, chromium, arsenic, lead, and antimony, and metal-organic compounds.
- Petroleum aliphatic hydrocarbons and halogenated aliphatic hydrocarbons.
- Cyanides or cyanide complexes.
- Aromatics (e.g., benzene, toluene, creosol, phenol).
- PCBs and chlorinated phenols.

- Water-soluble constituents.
- Basic organic constituents, such as amines, ethers, and anilines.

Ellis et al. (Ellis, 1978) reported that solvent extraction can be a viable method for treating soils contaminated with organics, as well as heavy metals. Their tests indicated that sequential treatments of soils with ethylene diamine tetracidic acid (EDTA), hydroxylamine hydrochloride, and citrate buffer were effective in removing metals from soils. The best inorganic removal efficiencies observed were as follows: cadmium (98 percent), lead (96 percent), copper (73 percent), chromium (52 percent), and nickel (23 percent).

These extraction processes are favorable for application if the soil to be treated primarily consists of sand particles. Organics, sludges, humus-like substances, and clay may pose difficulties in the implementability of extraction because of difficulty in separating the treated solids from the liquid phase.

Mobile, surface-mounted soil washing systems have been developed and tested (EPA, 1982). Soil washing systems have been developed to remove hazardous materials from contaminated soil following excavation. A prototype system capable of processing 4 to 18 cubic yards of soil per hour (depending on the soil particle size and the nature of the contaminant) has been devised.

Surfactants passing through a soil or sludge matrix can remove the adsorbed contaminants by substitution, emulsification, and/or solubilization. Laboratory studies have been conducted to determine whether aqueous phase extraction efficiency can be enhanced through surfactant addition to the water (EPA, 1985a). Various bench- and pilot-scale studies indicate that aqueous surfactant solutions may be applicable for in-situ treatment of slightly hydrophilic and hydrophobic organics from soils. In-situ operations are discussed in other sections of this report.

In general, the use of surfactants can increase the mobilization of the following contaminants: aliphatic hydrocarbons, benzene and substituted benzene, halogenated aromatic compounds, fused polycyclic hydrocarbons, fused non-aromatic polycyclics, ethers, heterocyclic nitrogen compounds, heterocyclic oxygen compounds, and heterocyclic sulfur compounds.

Excavation followed by extraction would require the construction of a soil processing plant, or the use of a mobile unit, and a means of treating or recovering the extraction fluid. Air monitoring may be necessary during the excavation and treatment.

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Contaminant nature.
- Soil type and organic fraction/partition coefficient.

3.1.5.2 Thermal Treatment

The May 19, 1980, Federal Register defines thermal treatment as "the treatment of hazardous waste in a device which uses elevated temperatures as the primary means to change the chemical, physical, or biological character or composition of the hazardous waste." A number of the thermal treatment systems are available as mobile units. Depending on the volume of soils to be treated, corrective measures with such mobile systems can be less expensive and more easily implemented, since offsite transport of waste materials or construction of onsite facilities would not be required. Thermal treatment processes can consist of either incineration or low temperature thermal treatment.

Incineration

Incineration is a thermal treatment process that uses controlled flame combustion in an enclosed reactor to decompose hazardous wastes (EPA, 1980). Incineration is essentially an oxidation process that converts organic wastes to inorganic substances (Brunner, 1984).

- Rotary Kiln Incinerators

    The rotary kiln incinerator is a refractory-lined cylinder that rotates slowly about an axis that is slightly inclined from the horizontal. Solid waste material is added at the upper end of the incinerator. As the incinerator rotates, the waste material moves to the lower end while combustion takes place. This rotation also causes mixing of the waste with combustion air to provide sufficient turbulence and agitation for adequate exposure of surface area of the waste. Combustion air enters the lower end of the incinerator and travel in the opposite direction of the waste. The heated combustion air dries the waste material as it moves across the material. A secondary, high-temperature, combustion chamber is sometimes necessary to complete the incineration of the vapor phase and particulate materials. Liquids and gaseous organic wastes can also be incinerated in the rotary kiln incinerator. Normal operating temperatures vary from 1,475° to 2,900°F (802° to 1,593°C), with residence times varying from a few seconds for gases to a few hours for solids.

Two types of rotary kilns are available. One is concurrent, with the burner at the same end as the waste feed. The other is countercurrent, with the burner at the opposite end of the kiln from the waste feed point.

Rotary kilns are the most highly developed hazardous waste incineration technology (Engleman and DeLes, 1983). Commercial mobile units and fixed units are available (Glynn and Kunce, 1986).

Rotary kilns are one of the most widely used types of incinerators for hazardous waste treatment. They have been used to treat solids, sludges, liquids, and gases. They have been tested on dioxin-contaminated soil; RCRA-listed substances such as dichlorobenzene, trichlorobenzene, tetrachlorobenzene, and tetrachloromethane (Freeman and Olexsey, 1986); solvent-contaminated soils; PCBs; acids; caustics; cyanides; oils; solvents/cleaners; various chlorinated organics; and pharmaceutical wastes (Camp Dresser & McKee, 1985b). Wastes with low inorganic salt and low mercury content are preferred for treatment in a rotary kiln. Wastes that have a high salt content, a high heavy metals content, or that are explosive require special evaluation before they can be treated in a rotary kiln incinerator. Organic removal efficiencies have been reported as greater than 99 percent (Glynn and Kunce, 1986). Throughput for mobile rotary kilns is approximately 6 tons per hour.

Air, liquid, and solid residuals are generated by this process (Johanson, 1983). Halogenated wastes produce acid gases; a scrubber is required to remove them from the air effluent. The scrubber water generally requires treatment before it is discharged (Ackerman, 1983). If metals are present in the waste material, the ash residue may present a disposal problem because the metals will remain in the ash (Camp Dresser & McKee, 1985b). Ash residue may require solidification before it can be landfilled if elevated concentrations of inorganics are present. Because of its general availability, broad range of applicability to a variety of wastes, long residence times, and high ambient reaction temperatures, rotary kiln incineration is amenable to treating the residual wastes and contaminated soils.

● Fluidized Bed

The fluidized bed incinerator consists of a refractory-lined vessel containing a bed of inert, granular, sand-like material (sized, crushed refractory). Solids, sludges, and liquids can be injected directly into the bed or at its surface. If contaminated soil is being processed, the

soil mass acts as the bed material. In one design (Waste-Tech), the decontaminated soils and heavy noncombustible inert material are continually withdrawn from the bottom of the vessel. During operation, combustion air is forced upward through the bed, which fluidizes the material at a minimum-critical velocity. The heating value of the wastes plus minimal auxiliary fuel maintains a desired combustion temperature in the vessel. The heat of combustion is transferred back into the bed, and the agitated mixture of waste, fuel, and hot-bed material in the presence of fluidizing air provides a combustion environment that resists fluctuations in temperature and retention time due to moisture, ash, or BTU content of the waste (EPA, 1988).

A secondary reaction chamber is employed to permit adequate retention time (over 2 seconds) for combustion of volatiles. Combustion gases are drawn out of the end of the secondary reaction chamber and treated for removal of acid gas and particulate constituents. Process residuals are decontaminated ash, treated combustion gases, and possibly wet scrubber water (EPA, 1988).

Fluidized beds can be operated at lower temperatures than other incinerators because of the high mixing energies aiding the combustion process. This mixing offers the highest thermal efficiency while minimizing auxiliary fuel requirements and volatile metals emissions. Fluidized bed systems may make use of in-bed limestone addition for acid gas capture, which removes the requirement for wet scrubbers and blowdown water treatment (EPA, 1988).

- Multiple Hearth/Fixed Hearth Incinerator

Multiple hearth incinerators are refractory-lined, vertical steel cylinders subdivided into horizontal stages (hearths). An air-cooled, rotating central shaft fitted with rabble arms conveys waste along the base of each stage to downcomers leading to the hearth below. Solid waste is introduced at the top of the incinerator. Liquid wastes can be introduced via burners located in the side of the incinerator. Auxiliary fuel burners and air inlets are located in the side of the incinerator. Air and combustion products flow upward, countercurrent to the waste. Exhaust gases are cooled and conveyed to air pollution control equipment. Ash is removed from the bottom of the incinerator, cooled, and transported for proper disposal. Multiple hearths are not available as mobile units.

This process is not suited for materials that are difficult to burn or that contain valuable metals which can be recovered (Kieng et al., 1982). It has been used on sludge, tars, and

solids, and can be used for gases or liquids. The multiple hearth incinerator is the most widely used method for sewage sludge incineration. Because of low operating temperatures and short residence times, efficiency of waste destruction may be lower than the other types of incinerators.

The composition of waste streams from multiple hearth incinerators is dependent upon the nature of the wastes treated. Gaseous emissions will occur, and adequate treatment of the off-gas is required.

Although multiple hearth incinerators are commercially available, hazardous waste incineration by this method has not been extensively tested. Other thermal treatment technologies described herein have proven track records treating organic contaminated soils and therefore are preferred over multiple hearth incineration.

Incinerators can effectively destroy a wide variety of organic wastes. Commercial facilities such as cement kilns and asphalt manufacturers can accept contaminated soils provided the contaminants and type of soil do not affect the quality of the product adversely. Combustible wastes are acceptable at these facilities provided the heat content does not exceed certain upper limits.

Low Temperature Thermal Treatment/Stripping (LTTS)

LTTS is a process that uses direct or indirect heating to thermally desorb or volatilize organic contaminants present in soils/sediments. LTTS is applicable to the removal of VOCs (organic compounds whose Henry's Law constant >3.0 atm L/mol). The normal range of operating temperatures in LTTS is approximately 150°F to 800°F. The actual temperature of operation is contaminant- and matrix-specific. The effectiveness is affected by the type of waste. Soils/sediments with a high clay content and high moisture content are normally less amenable to adequate treatment by LTTS than sandy soils. A sampling of available LTTS equipment in the market is described in some detail below:

- Chemical Waste Management offers a proprietary process called X*TRAX. This process consists of a rotary dryer externally fired with propane and an off-gas handling system. Contaminated soils are fed in by an auger and heated to a temperature range of 500°F to 800°F. Nitrogen is used as a carrier gas which conveys volatilized water and organics to a baghouse and then to a three-stage cooling and condensing train. Organics in the liquid condensate are removed for disposal. The carrier gas is reheated and recycled. A part of

the carrier gas is filtered and treated by activated carbon adsorption prior to being vented. The full scale model handles an average 150 tons per day of soil with a moisture content of 20 percent. It requires 120 feet by 120 feet of space to set up and 2 to 3 weeks mobilization time (Swanstrom, 1991 and Swanstrom et al., 1991). The X*TRAX system mechanical feed system is specifically designed to handle soils of high clay content (Swanstrom, 1992, personal communication).

- Weston Services, Inc. has a patented Low Temperature Thermal Treatment (LT3) system. The system uses a thermal processor which is an indirectly heated auger-type heat exchanger. The processor is operated at approximately 400°F. Sweep gas, a mixture of air and exhaust gases from the indirect firing system (fired on propane, natural gas, or oil), carries volatiles to a baghouse, then through two condensers prior to being treated by activated carbon adsorption (Nielson et al., 1989 and Cosmos, 1992, personal communication). The full-scale model is designed to process 7 tons per hour with a moisture content up to 20 percent. Mobilization takes 1 to 2 weeks and requires approximately 100 feet by 100 feet of space for equipment setup (Cosmos, 1992, personal communication).

- Clean Soils, Inc. provides a LTTS system called a Thermal Desorber. The three major components of the system consists of a primary treatment unit, a baghouse, and a secondary treatment unit. The primary treatment unit is a rotary chamber in which the soil is heated to 350°F to 700°F. Off-gas from this unit, which contains both particulates and volatilized organics then passes through a baghouse. The particulates are collected in the baghouse and recirculated back to the primary soil discharge. The filtered exhaust gas then enters an afterburner (or thermal oxidizer) where a temperature of 1,400°F or higher is maintained and residual organics in the exhaust gas are oxidized. The Thermal Desorber can remove any organic of low volatility or with boiling point below operating temperature, and oxidize it to carbon dioxide and water (CleanSoils Inc., company brochure).

The heat content of the waste and nature of organic contaminants are important parameters affecting the LTTS process. The type of soil can also pose certain limitations on the effectiveness of this technology.

3.1.5.3 Solidification/Stabilization

The purposes of solidification/stabilization are to improve waste-handling characteristics, immobilize highly soluble compounds, minimize the potential for leaching, and/or detoxify the waste (EPA, 1986a; Loynachan, 1978). Inorganic contaminants are most often chemically treated to reduce their mobility, and then the waste matrix is solidified. Organic contaminants are less amenable to such chemical treatment and are often immobilized by encapsulating the entire waste in impermeable materials.

Chemical Fixation/Solidification

Typically, chemical fixation/solidification processes are cement/pozzolan-based processes. Cement-based methods involve sealing the waste in a matrix of Portland cement. Waste constituents are physically and/or chemically bound into the matrix, depending on the type of waste. A number of additives have been developed for use with cement to improve the physical characteristics and decrease the leaching loss from the solidified waste. Many of these additives are proprietary. Common additives include clay, vermiculite, soluble silicates, sodium silicate, and fine-grained silica (CDM, 1985a).

Lime/pozzolanic-based methods are similar to cement-based solidification. The method involves the reaction of lime with fine-grained siliceous materials plus water to produce a concrete-like end product (sometimes referred to as pozzolanic cement). Common materials used are fly ash, blast furnace slag, and cement kiln dust (CDM, 1985a; EPA, 1982). The chemical reactions involved are often not well defined: Typically, solidification reactions are slow (Smith, 1985). The end product is generally a solid with improved handling and permeability characteristics (EPA, 1982).

Standard cement mixing and handling equipment is generally used for these methods. However, some vendors use patented mixing and material-handling equipment.

Key operating parameters are the fixative to waste ratio, length of time for setting and curing (generally 1 to 2 days), required structural integrity, and minimized potential for leaching (CDM, 1985a; EPA, 1986a).

Cement-based methods are well suited for heavy metals and, to a limited extent, for organics (generally no more than 20 percent by volume) (EPA, 1986a). It is well known that organics can alter the setting characteristics of cement. It is not clear whether, and at what concentrations, organics can interfere with the relatively complex setting reactions, which would result in a significantly altered

cement matrix. Organics (such as solvents and oil) can interfere with the set and cure of cement. Sulfates can retard setting and cause swelling. Soluble salts of many metals can also interfere with the set/cure of cement and can reduce the ultimate strength (EPA, 1986a; CDM, 1985a; EPA, 1982). When attempting to fix organics in a cement matrix, little, if any, chemical bonding takes place. The physical encapsulation obtained may be insufficient, which may allow organic molecules to move through the solidified matrix. The decomposition of organic materials after curing can result in an increase in permeability along with a decrease in strength. Pretreatment may possibly be used to remove interfering constituents (EPA, 1986a; CDM, 1985).

The volume and weight of wastes solidified by these methods could be double that of the raw waste (Smith, 1985; EPA, 1986a). Products from uncoated cement- and lime-based methods may require specially designed landfills to guarantee that the material does not lose potential pollutants by leaching (EPA, 1982).

The following parameters are important in assessing the implementability and/or effectiveness of this technology:

- Contaminant nature, soil type, etc.
- Presence of oil and grease, sulfates, soluble salts, etc.

Encapsulation

Macroencapsulation and microencapsulation are two forms of encapsulation. In these technologies, the contaminated soils/sediments are excavated and treated to render them physically immobile in the environment.

- Macroencapsulation

  Macroencapsulation, also called jacketing, isolates the waste by completely surrounding it with a durable, impermeable coating. Methods include sealing the waste in fiberglass containers and then coating them with a thermoplastic covering and overpacking standard, 55-gallon drums with welded polyethylene containers (Lubowitz and Wiles, 1981). These methods are most applicable to wastes stored in 55-gallon drums as a means of preventing leakage. Another method, investigated by TRW, Inc., for the EPA (EPA, 1977), involves mixing the waste with an organic polymer (microencapsulation) and then compressing the mixture into a polyethylene-coated block using a pressure/heating technique (macroencapsulation).

Macroencapsulation processes are complicated, expensive, and energy-intensive. Equipment, as well as the resins, are typically very expensive. Skilled labor is required to operate the equipment. Currently, very few vendors have experience with macroencapsulation techniques. Macroencapsulation could require disposing the treated material in a RCRA hazardous waste landfill since no reduction in organic contaminant concentrations would be achieved by this treatment method.

Macroencapsulation does not reduce the volume or toxicity of the contamination. The results of laboratory tests on a polyethylene encapsulate for a polyester stabilized product show compressive strengths comparable to cement-based products (Camp Dresser & McKee, 1985a). A process that involves microencapsulation prior to macroencapsulation, such as the TRW process, would probably be more effective in immobilizing contaminants than a process that consists solely of macroencapsulation.

- Microencapsulation

Thermoplastic microencapsulation techniques involve mixing the dried waste with materials such as bitumen, paraffin, polyethylene, or elemental sulfur at high temperature (130°C to 260°C) and then placing the mixture in a container or mold where it solidifies as it cools. Thermoset processes use organic polymers, such as urea-formaldehyde, polyesters, and phenolics, which harden and become solid when mixed with a catalyst. With these microencapsulation processes, excavated soils would be mixed with polymeric substances, or other materials such as asphalt bitumen, in an extruder to form a solid product. The contaminants in the extruded product are entrapped in a polymer matrix, which is dispersed throughout the soil.

Implementation of thermoplastic technology involves complex, expensive equipment requiring highly specialized labor. Thermoplastics are flammable and therefore require careful process control and health and safety measures. Currently, very few vendors have experience with using thermoplastic microencapsulation techniques. Thermoplastic microencapsulation could require disposing the treated material in a RCRA hazardous waste landfill because such treatment would not result in a reduction in the mobility of contaminants by chemical treatment.

Because the catalysts used in thermoset processes are highly acidic, heavy metals go into solution prior to being fixed in the thermoset matrix and are, therefore, not stabilized

(Camp Dresser & McKee, 1985a). The most commonly used thermoplastic material is asphalt or bitumen. Experiments using asphalt/sulfur blends to encapsulate metals indicated that the solidified product exhibited strong resistance to chemical and mechanical stresses (Brenner and Rugg, 1982).

Encapsulation techniques of contaminated soil/sediments has not been well demonstrated and would involve more complicated and expensive equipment than other processes. For these reasons, they are not likely candidates for implementation at the Calverton NWIRP.

3.1.5.4 Biological Treatment

Soils contain a variety of microorganisms that are capable of degrading hydrocarbons and other contaminants. Native bacteria, actinomycetes and other microbes present in contaminated soils can be acclimated to metabolize the contaminants in their natural environments. The carbon present in hydrocarbon contaminants is converted to microbial cell mass and carbon dioxide. Typically n-alkanes, n-alkylaromatics and aromatic petroleum components containing between 10 to 22 carbon atoms per molecule are the least toxic and most biodegradable. Among the compounds present in petroleum fractions, benzene and toluene, which are known to be toxic to human beings, are relatively biodegradable (EPA, March 1990). The petroleum industry has exploited this ability of native soil microbes to biodegrade petroleum hydrocarbons for the land treatment of petroleum refining wastes. Land treatment uses farming techniques to "cultivate" microbes in the contaminated soils to achieve aerobic biodegradation of the contaminants.

Landfarming for contaminated soil treatment involves excavation of the contaminated soils and spreading the soils in a 0.5- to 1.5-foot layer on a lined treatment bed. Environmental conditions suitable to the growth of aerobic microbes such as nutrients/micronutrients, pH and moisture content are maintained in the soil by addition of appropriate chemical solutions. Bartha and Bossert (1981) have reported that the proportion of nutrients (C:N:P::60:1:0.075) is optimum for biodegradation of oil sludge degradation. Adequate oxygenation of the soils is provided by exposing the soils periodically to the atmosphere by rototilling, discing, or other such soil-turning technique. The optimum temperature and pH ranges for oil sludge biodegradation have been reported to be 7.5 to 7.8 and 68°F to 104°F, respectively (Atlas, 1981). The moisture content for optimal microbial activity must be maintained between 50 and 80 percent water holding capacity (Bossert and Bartha, 1984). If ambient temperature is not suitable to optimum microbial activity, then landfarming would require artificially maintained, enclosed conditions. Fully enclosed "greenhouse"-like structures with off-gas emissions control would also be necessary if the levels of VOCs expected in the air emissions are of concern. The availability of adequate space is an important criterion for the implementability of this

technology. The type of soil is another important criterion because soils with a high clay content are difficult to mix and aerate.

Bioslurry treatment is a liquid-phase treatment of the contaminated soils, unlike landfarming, which is a solid-phase treatment technology. In this technology, the contaminated soils are excavated and mixed in a reactor with an aqueous mixture of nutrients and acclimated microbes to form a slurry. The contaminants are desorbed and solubilized into the aqueous phase, making it more amenable to biodegradation. After an appropriate hydraulic retention time (which will depend on contaminant-specific kinetics), the slurry is transferred into a sedimentation tank for solids separation. The liquid from the slurry can be discharged after further treatment with activated carbon adsorption, if required. The solids containing decontaminated soil and microbial mass is partially recycled to the reactor to maintain the microbial population in the reactor or disposed of after dewatering. Because of it similarity to soil washing techniques, implementability concerns attached to the the type of soil are also valid for bioslurry treatment.

3.1.5.5 Chemical Treatment

Chemical treatment involves the use of chemical reagents to destroy and/or reduce in toxicity target compounds. The reagents could consist of oxidizing reagents which may partially or completely convert chlorinated hydrocarbons to hydrochloric acid, water, and carbon dioxide. Under similar conditions, inorganic chemicals would be converted to a higher oxidation state. Chemical treatment also consists of chemical reduction (lowering of the oxidation state) and substitution (no increase or decrease in oxidation state).

Consideration of chemical dechlorination at site would target PCBs. Based on available processes, chlorinated volatile organics would volatilize and be captured for separate treatment.

Chemical treatment of chlorinated organics associated with soils and sediments is not a well established technology. One chemical dechlorination process commercially available for aromatic halogenated compounds in soils, sludges, and oils is the APEG (alkaline-polyethylene glycolate) process (Galson Research Corporation). This process is used primarily for the dechlorination of mineral oils containing approximately 1 percent or less of PCBs. At higher PCB concentrations, the process is not economically competitive with incineration.

In the APEG process, contaminated soil/sediment is mixed with an alkaline reagent consisting of potassium hydroxide in a solution of mixed polyethylene glycol and dimethyl sulfoxide. The reagent mixture dechlorinates the aryl halide to form a PEG ether, which may further degrade to form a

totally dechlorinated species. The soil and reagent are heated to a temperature of 86°F to 302°F and mixed until the reaction is complete. Some of the metals present in the soil will be converted to metal hydroxides by the action of the alkali. At the end of the reaction, the reagent is recovered by decanting and washing the soil with several volumes of water. For soils containing high concentrations of volatile organics, the volatile organics would be volatilized and condensed during a pretreatment distillation stage for subsequent treatment and/or disposal. The decontaminated soil is then discharged and the reagent is recycled.

Other chemical dechlorination processes are available which are based on the use of metallic sodium to sequentially strip chlorine atoms from the PCB. Because of the metallic sodium, these processes require that the moisture content be minimal (less than 0.01 percent). This limits these processes to mineral oil-based fluids.

The requirements needed to evaluate the use of chemical dechlorination include chemical concentrations, moisture content, and because the process is not well established, treatability studies to determine effectiveness and costs.

3.1.6   Offsite/Onsite Landfill Disposal

Landfilling is a technology that could be implemented by utilizing an onsite or offsite, nonhazardous waste landfill or RCRA hazardous waste landfill. Secure landfills are regulated by the requirements of RCRA, state, and local laws and regulations. Because some of the SWMUs could possibly contain hazardous waste, residual wastes and contaminated soil excavated from these units could be subject to the requirements of RCRA Subtitle C including the Land Disposal Restrictions (LDR). Disposal of hazardous waste in a RCRA hazardous waste landfill will require treatment to standards specified by the LDR, as required based on the waste concentration. Disposal of treated wastes in a nonhazardous waste landfill would require that the material be delisted prior to disposal. Nonhazardous materials will be subject to the state regulations.

Among the requirements of a RCRA hazardous waste landfill are liner systems, leak detection systems, leachate collection and treatment systems, capping, and long-term monitoring. Federal requirements for hazardous waste landfill construction are contained in 40 CFR 264.301 (design and operating requirements for landfills). Two or more liners with a leachate collection system above and between the liners are required.

The evaluation of onsite versus offsite landfilling will depend on a number of factors including the following:

- RCRA characteristics or presence of hazardous substances in excavated materials (including toxicity characteristics leaching procedure and free liquids tests).

- Location of permitted offsite RCRA hazardous waste and solid waste landfills.

- The types and costs of hazardous waste treatment required by LDRs.

- Cost evaluations of offsite disposal versus construction and operation and maintenance of onsite landfills.

- Availability of suitable onsite landfill locations.

These factors will be considered in more detail after the RFI as part of the Corrective Measures Study.

3.2   GROUNDWATER/SURFACE WATER

3.2.1   No Action

No Action consist of allowing the groundwater and surface water to remain status quo. Under this condition, the contamination in the water will remain at original concentrations, and any reduction will be due to natural attenuating factors such as dilution, dispersion, adsorption, infiltration, etc.

3.2.2   Groundwater Control/Removal

Groundwater contaminant plume control may be achieved by: (1) hydrodynamic controls and (2) subsurface barriers. Groundwater removal may be achieved by subsurface drains or extraction wells.

3.2.2.1   Hydrodynamic Controls

Hydrodynamic controls are employed to isolate a plume of contamination from the normal groundwater flow regime to prevent the plume from moving into a well field, another aquifer, or surface water. Isolation of the contaminated plume is accomplished when uncontaminated groundwater from upgradient areas is circulated around the plume using injection and extraction

wells. The circulated zone creates a groundwater (hydrodynamic) barrier around the plume. Groundwater upgradient of the plume will flow around the circulated zone where as groundwater downgradient will be essentially unaffected. The effectiveness of hydrodynamic controls depends on the ability to maintain a closed-loop extraction/injection system, which in turn, depends on the local hydrology and aquifer characteristics.

Well Systems

Well systems are used for hydrodynamic control of contaminated plumes by manipulating the hydraulic gradient of groundwater through injection and withdrawal of water. The three general classes of well systems include (1) well-point systems, (2) deep-well systems, and (3) pressure-ridge systems. All three types of well systems may require the installation of multiple wells at selected sites.

Well-point systems consist of a series of closely spaced, shallow wells connected to a main header pipe that is connected to a suction lift pump. Well-point systems are used only for shallow aquifers because of the drawdown limitations as determined by the static water level and the limits of the pump. These systems should be designed so that the drawdown of the system completely intercepts the plume of contamination.

Deep wells are similar to well point systems except they are used for greater depths and are normally pumped individually. These wells are used in consolidated formations where the water table is too deep for economical use of suction lift systems. Since the maximum depth for suction lift is about 25 feet, deep wells normally employ jet ejector or submersible pumps.

Pressure Ridge Systems

Pressure-ridge systems are produced by injecting noncontaminated water into the subsurface, through a line of injection wells, either upgradient or downgradient from a plume of contamination. Upgradient ridges or mounds are used to force upgradient, uncontaminated groundwater to flow around a contaminant plume while the contaminants are being collected by a line of downgradient pumping wells. Pressure-ridge systems located downgradient are normally used in combination with upgradient pumping wells, which supply uncontaminated injection water. In either case, the injection of fresh water produces an uplift or mound in the original water table which acts as a barrier by forming a ridge which pushes the contaminated plume away from the mound.

3.2.2.2 Subsurface Barriers

The term "subsurface barriers" refers to a variety of methods whereby low-permeability cut-off walls, or diversions, are installed below ground to contain, capture, or redirect groundwater flow in the vicinity of a site. The most commonly used subsurface barriers are slurry walls, particularly soil-bentonite slurry walls. Less common are cement-bentonite slurry walls and sheet piling cutoffs.

Slurry walls are the most common subsurface barriers because they are a relatively inexpensive means of vastly reducing groundwater flow in unconsolidated earth materials. The term slurry wall can be applied to a variety of barriers all having one thing in common: they are constructed in a vertical trench that is excavated by conventional techniques (i.e., using a backhoe and sheeting and shoring to keep the trench walls in place until backfilled) or by other methods such as using a biopolymer slurry to keep the walls in place. The slurry supports the walls temporarily while excavated materials are removed and drainage structures are installed. The biopolymer slurry then naturally biodegrades after the trench is backfilled. Slurry wall types are differentiated by the materials used to backfill the slurry trench. Most commonly, an engineered soil mixture is blended with the bentonite slurry and placed in the trench to form a soil-bentonite (SB) slurry wall. In some cases, the slurry wall consists of Portland cement and bentonite, which hardens to form a cement-bentonite (CB) slurry wall.

One factor that can limit the use of a soil-bentonite wall is the site topography. Because both the excavation slurry and the backfill will flow under stress, the trench line must be within a few degrees of level. In most cases, it is possible to grade the trench-line level prior to constructions, but this is an added expense.

Yet another limiting factor in the use of soil-bentonite slurry walls for pollution migration control is the lack of long-term performance data. Soil-bentonite walls have been used for decades for groundwater control in conjunction with large dam projects, and there is ample evidence of their success in this application. However, the ability of these walls to withstand long-term permeation by many contaminants is questionable. Most contaminant/backfill compatibility questions have been answered by laboratory permeation tests and not by long-term field studies.

Another major concern in the application of soil-bentonite walls to site remediation is the compatibility of the backfill mixture with site contaminants. Evidence indicates that soil-bentonite backfills are not able to withstand attack by strong acids and bases, strong salt solutions, and some organic chemicals (Dappolonia, 1980). Cement-bentonite mixtures are somewhat more susceptible to chemical attack than most soil-bentonite, and should not be placed directly through wastes or left unprotected from attack by high-strength leachates, organic free product contamination, etc.

3.2.2.3 Removal

Removal of groundwater for above-ground treatment is a common method of groundwater remediation. Two process options could be implemented to transfer groundwater to the surface: (1) extraction using a pumping well system, and (2) extraction through subsurface drains. Removal of surface water for treatment would require pumping the water using centrifugal pumps into the treatment process.

Extraction Wells

Groundwater pumping techniques involve the active manipulation and management of groundwater to contain or remove a plume or to adjust groundwater levels so as to prevent formation of a plume. The selection of the appropriate well system depends upon the depth of contamination and the hydrologic and geologic characteristics of the aquifer. Well systems are very versatile and can be used to contain, remove, divert, or prevent development of plumes under a variety of site conditions.

Subsurface Drains

Subsurface drains include any type of buried conduit that is used to convey and collect aqueous discharges by gravity flow. Subsurface drains essentially function like a continuous line of extraction wells. They create a continuous zone of influence in which groundwater within this zone flows toward the drain.

The major components of a subsurface drainage system are as follows:

- **Drain pipe or Gravel Bed**. Used for conveying flow to a storage tank or wet well. Pipe drains are used most frequently at hazardous waste sites. Gravel bed or French drains and tile drains are also used, although to a more limited extent.

- **Envelope**. Permeable material (i.e., gravel) used for conveying flow from the aquifer to the drain pipe or bed.

- **Filter**. Used for preventing fine particles from clogging the system, if necessary.

- **Backfill**. Soil above saturated zone used to bring the drain to grade and prevent ponding.

- **Manholes or Wet Wells**. Used to collect flow and pump the groundwater to a treatment plant.

Since drains essentially function like a line of extraction wells, they can perform many of the same functions as wells. They can be used to contain or remove a plume, or to prevent contact of water with the waste material.

The most widespread use of subsurface drains at hazardous waste sites is to intercept a plume hydraulically downgradient from its source. For this type of application, pipe drains are most frequently used. French or gravel drains can be used where the amount of water to be drained is small and flow velocities are low. If used to handle high volumes, or rapid flow, these drains are likely to fail due to excessive siltation, particularly in fine-grained soils. Tile drains have not been widely used in hazardous waste site applications. The use of subsurface drains is limited by depth considerations. Depths of greater than 25 feet require the use of specialized trenching equipment. Unit costs for trenching increase with greater depth requirements.

In addition to depth, other limitations to the use of subsurface drains include the presence of viscous or reactive chemicals which could clog drains and envelop material. Conditions which favor the formation of iron, manganese, or calcium carbonate deposits may also limit the use of drains. The design of an effective groundwater removal system depends to a large extent on the available data on the contaminant plume, geology/hydrogeology, and hydraulic characteristics of the aquifer.

The parameters affecting the implementability and effectiveness of groundwater control/removal may be summarized as follows:

- Hydrology/aquifer characteristics.
- Topography and depth to confining layer.
- Nature of contaminants and presence of floating/sinking organic free product.
- Thickness of aquifer, recharge rates, etc.
- Potential for clogging due to precipitation, fine soil material, etc.

3.2.3   In-situ Treatment

In-situ treatment technologies are applicable to groundwater remediation rather than to surface water. In-situ treatment involves the remediation of the groundwater within the formation in which

it is present with a limited extent of extraction and injection. The two main technologies considered here are in-situ air sparging and in-situ biological treatment.

3.2.3.1 Air Sparging

Air sparging was briefly discussed within in-situ air sparging and vapor extraction/bioventing as a method to remediate the saturated zone soils. In this technology, the removal of the contaminants is achieved by air stripping/biodegradation of VOCs and biodegradation of the semi-VOCs. Most petroleum hydrocarbon contaminants are amenable to removal from the saturated zone using this technology. Air stripping and biodegradation of contaminants can occur simultaneously in the groundwater as well as in the saturated zone soils.

3.2.3.2 In-situ Biological Treatment

In-situ bioremediation is a process by which microorganisms biologically degrade organic compounds to less harmful degradation products, such as carbon dioxide, methane, and water. This process is conducted in the subsurface by providing the indigenous microorganisms optimum conditions for growth, such as pH, nutrients. Biodegradation can be conducted under aerobic conditions by supplying a sufficient source of oxygen or under anaerobic conditions by removing the oxygen from the subsurface. The conditions chosen (i.e., aerobic or anaerobic) are dependent on the chemical compounds to be remediated and ease of implementation. Historically, petroleum compounds are known to be more susceptible to aerobic biodegradation than to anaerobic biodegradation. Moreover, anaerobic biodegradation of chlorinated aliphatic compounds is incomplete and leads to the formation of more toxic compounds. Therefore, only aerobic bioremediation will be discussed here.

Aerobic Bioremediation

This process involves stimulation of the indigenous aerobic microflora in the subsurface to enhance the biodegradation of contaminants by providing a supply of oxygen and nutrients. In some cases, a cometabolite or an additional carbon source is necessary to achieve biodegradation.

Oxygen may be provided in the form of air, pure oxygen, or hydrogen peroxide. The oxygen may either be added to the extracted groundwater prior to reinjection, directly bubbled in through spargers, or supplied by in-line injection of pure oxygen. The use of hydrogen peroxide leads to certain advantages such as a greater supply of oxygen and control of biofouling of the well.

Nutrients such as nitrogen and phosphate are essential for microorganisms, and may be present in limited concentrations in the subsurface. The forms of nitrogen and phosphorus are not critical. However, the decision to add salts as nutrients must be based not only on laboratory tests for microbes, but also on potential interaction with the site geochemistry. Certain nutrients such as phosphates could result in the precipitation of calcium phosphate, which may clog pores and reduce the permeability of the subsurface. If the contamination is relatively low, it may be necessary to add an additional carbon source to support sufficient bacterial growth. The selection of this additional carbon source is critical. The compound that is selected must not be preferentially biodegraded over the contaminants of concern. In addition, the compound should be innocuous so that it will not adversely affect the groundwater. Other microbial nutrients such as potassium, magnesium, calcium, sulfur, sodium, manganese, iron, and trace metals may be already present in the groundwater.

Under aerobic conditions, petroleum hydrocarbons are more readily biodegradable than chlorinated aliphatics such as TCE. TCE and 1,2-DCE, which is a degradation product of TCE, have previously been shown to be resistant to biological degradation (Bouwer and McCarty, 1981).

Recently two pilot-scale studies were conducted which demonstrated that TCE could be aerobically degraded. The first study was conducted by Ecova Corporation (Nelson et al., 1990) for a Fortune 100 company. The study demonstrated that 3,000 ppb of TCE was reduced to 100 ppb in 7 days. Ecova introduced organic and inorganic nutrients, oxygen, and specific TCE-degrading bacteria using a proprietary process.

The second study was conducted by Stanford University for EPA's Robert S. Kerr Environmental Research Laboratory. The study was conducted at the Moffett Naval Air Station in California and utilized indigenous methane-oxidizing bacteria to degrade TCE. This study provided nutrients and alternating doses of oxygen and methane (12-hour cycles) to the subsurface. The results of the study demonstrated 30 percent degradation of TCE (Lee et al., 1988).

The effectiveness of in-situ biodegradation in a field study would be difficult to conclusively demonstrate owing to two main reasons (Madson, E. L., 1991):

- Evaluation of mass balance attributable to biodegradation alone is intractable since various abiotic processes such as dispersion, dilution, sorption, and volatilization would be pathways of comparative effectiveness for removal of organics.

- Petroleum-degrading bacteria are not readily, morphologically distinguishable from the myriad of other organisms in the subsurface. Hence, any rapid growth in their numbers as a result of successful adaptation would be difficult to discern.

However, certain parameters that may be indicative of biodegradation would help distinguish biological degradation from removal by physico-chemical process. Such parameters are the production of metabolic intermediates/end products; consumption of cometabolites; stimulus-response testing of a portion of the site or as a pulse in time; reduction in the ratio of biodegradable to nonbiodegradable contaminants, etc. (Madson, E. L., 1991). Hence, extensive monitoring of all these parameters would be necessary to evaluate the effectiveness of in-situ biodegradation.

Ideally, in-situ biological degradation (in the aqueous phase) would be used in combination with an extraction system and would likely reduce the total time of remediation. However, the actual extent of bioremediation achievable would be difficult to predict unless the hydraulic conductivity of the subsurface is found to be conducive to achieve adequate dispersion of nutrients and oxygen, which are vital factors for bioremediation.

The following parameters can aid in evaluating the effectiveness and implementability of in-situ treatment:

- Hydrology/aquifer characteristics.
- Nature of contaminants.
- Presence of biodegradable compounds (measured by oxygen demand for oxidation), nutrients (nitrogen, phosphorus), micronutrients (trace metals, salts, sulfur), calcium and TDS.

3.2.4   Ex-Situ Treatment

Ex-situ treatment consists of the use of technologies for the treatment of groundwater after extraction or surface water after pumping.

3.2.4.1 Nonaqueous-Phase Liquid (NAPL) Removal

NAPL is the organic free-product that is present as a immiscible layer in the groundwater, because of its limited solubility in water. Expedited removal of NAPL is important to prevent any further increase in contamination of the groundwater.

NAPL free-product consisting of petroleum compounds is normally less dense than water and exists as a floating organic layer on the water table. This floating free-product can be removed from the water table by: (1) pumping the groundwater along with the free product, followed by oil/water separation, (2) pumping the oil and water separately, or (3) by vacuum extraction.

Pumping the groundwater along with the free-product can be applied when the free-product layer is of insufficient thickness for pumping the two layers separately. The process of pumping causes the oil to mix intimately with the water, thus requiring separation of the two above ground in an oil/water separator. Alternatively, the groundwater may be recovered in a trench in which a skimmer may be installed for removal of the floating free product. The floating free product alone can also be removed by using a hydrophobic (water-repelling) filter around the well casing which selectively allows the oil to flow into the well. The oil is collected in a chamber within the well, from which it is pumped to the surface.

The groundwater and the free product can be pumped separately. This method can be applied when the groundwater is also to be extracted for treatment, and when the free product is sufficiently thick to be pumped.

Vacuum extraction can be applied when the free product consists of relatively volatile petroleum fractions such as gasoline. In this method, extraction wells are placed in the unsaturated zone above the floating free product, and the vapors are extracted. As the vapors are withdrawn, more of the free product volatilizes to maintain the vapor-liquid equilibrium in the subsurface. Thus the free product is removed by volatilization and collected above ground by condensation. However, the effectiveness of this process is dependent on several site-specific physical/chemical factors such as the soil air conductivity, temperature, moisture content, soil particle characteristics, and organic carbon content of the soil (EPA, June 1990). Further, the applicability of this technology for free product recovery is limited to petroleum fractions that have a high vapor pressure and low aqueous solubility.

3.2.4.2   Air/Steam Stripping

Air Stripping

Air stripping is a mass transfer process in which volatile contaminants (compounds with Henry's Law constant >3.0 L atm/mol) in water or soil are transferred to gas. There are five basic equipment configurations used to air strip liquids: packed columns, cross-flow towers, coke tray aerators, diffused air basins, and mixing jets.

Air stripping is frequently accomplished in a packed tower equipped with an air blower. The packed tower works on the principle of countercurrent flow. The water stream flows down through the packing while the air flows upward, and is exhausted through the top. Volatile, soluble components have an affinity for the gas phase and tend to leave the aqueous stream for the gas phase. In the cross-flow tower, water flows down through the packing as in the countercurrent packed column; however, the air is pulled across the water flow path by a fan. The coke tray aerator is a simple, low-maintenance process requiring no blower. The water being treated is allowed to trickle through several layers of trays. This produces a large surface area for gas transfer. Diffused aeration stripping and induced draft stripping use aeration basins similar to standard wastewater treatment aeration basins. Water flows through the basin from top to bottom or from one side to another with the air dispersed through diffusers at the bottom of the basin. The air-to-water ratio is significantly lower than in either the packed column or the cross-flow tower. Mixing jet systems involve high intensity mixing of pressurized air and water. The air-to-water flow ratio, temperature of the water, and height of packing may be adjusted to achieve adequate removal of VOCs to meet discharge standards. Typically, pretreatment for removal of suspended solids, organic-free product, and scaling constituents would be required for air stripping.

Steam Stripping

Steam stripping is a unit process that uses steam to extract organic contaminants from a liquid or slurry. Steam stripping by direct injection of steam can be used to treat aqueous and mixed wastes containing organic contaminants at higher concentrations and/or having lower volatility than those streams which can be stripped by air. Direct injection of steam and multiple pass heat exchangers are the two most prevalent methods of steam stripping. It is an energy-intensive process and the steam may account for a major portion of the operating costs. This process is similar to steam distillation except that reflux of the stripped and recovered material does not usually occur.

3.2.4.3 Activated Carbon Adsorption

A large variety of organic contaminants and some inorganic ionic species that are commonly found in groundwater are amenable to removal by adsorption onto activated carbon. Contaminants adsorb to the internal pore surfaces of activated carbon particles as the contaminated water passes through a column of the activated carbon. When all the available surface area of the activated carbon particles is occupied, the column must be replaced by fresh activated carbon. The spent activated carbon must then be reactivated by incinerating the contaminants and rejuvenating the pores and re-exposing the internal surfaces.

Among organic contaminants, long-chain, low solubility, less polar compounds have a greater affinity for adsorption than others. The adsorption of organic acids is favored by low pH conditions in the water, whereas that of organic bases is favored by high pH conditions.

The presence of high levels of suspended solids can clog the flow of water through the column. The presence of organic-free product can hinder the adsorption of target dissolved contaminants by coating the surfaces and exhausting the column quickly. Because of the nonselective nature of this technology, the presence of naturally-occurring organic substances can increase the consumption rate of activated carbon.

3.2.4.4 Enhanced Oxidation

Enhanced oxidation processes use a controlled combination of ozone or hydrogen peroxide and ultraviolet light to induce photochemical oxidation of organic compounds. Ozone has been used extensively in Europe for purification, disinfection, and odor control of drinking water. Ozone alone has the ability to break down some organics but has generally proved to be an ineffective oxidant of halogenated organics under conditions normally used for drinking water treatment or for disinfecting wastewaters (i.e., 1 to 10 mg/L concentration levels and 5- to 10-minute contact times) (Brenton et al., 1986; Arienti et al., 1986). Oxidation of organic species to carbon dioxide, water, etc., however, is possible if the ozone dosage and contact times are sufficiently high (EPA, 1987). Hydrogen peroxide can be used as an alternative to ozone for water treatment.

Ultraviolet (UV) light is electromagnetic energy whose wavelengths fall between those of visible light and X-ray radiation on the electromagnetic spectrum. UV energy is capable of breaking down or re-arranging a molecular structure, depending on the dissociation energies of the chemical bonds within the structure (EPA, 1987). The combination of ultraviolet radiation with ozone treatment

results in the oxidation of organic contaminants at a rate many times faster than that obtained from applying UV light or ozone alone (McShea et al., 1987).

Ultraviolet light photolyzes hydrogen peroxide into highly reactive radicals. In addition, UV light either directly oxidizes, or splits organic molecules into more reactive species, thereby enhancing the oxidation reaction (Bernardin, F. C., and Froelich, E. M., 1990).

A typical continuous-flow enhanced oxidation system consists of an oxygen or air source, an ozone generator or hydrogen peroxide feed system, a UV/oxidation reactor, and an off-gas ozone decomposer. Flow patterns and configurations are designed to maximize exposure of the oxidant-bearing wastewater to the UV light, which is supplied by an arrangement of UV lamps. Typical reactor designs range from mechanically agitated reactors to spray, packed, and tray-type towers. Reactor gases are passed through a catalytic decomposer, which converts remaining ozone to oxygen and destroys any volatiles. The gases are then discharged or recycled. Hydrogen peroxide is gaining importance as a supplement or replacement for ozone.

Pretreatment for the removal of suspended solids, iron, manganese, organic-free product and scale-forming constituents is important.

3.2.4.5 Precipitation/Suspended Solids Removal

Precipitation is a process wherein dissolved inorganics contaminants are rendered insoluble by the addition of chemicals. The process is based on the alteration of the chemical equilibrium of the ionic species in solution with the insoluble compounds. The precipitates, however, are not readily separable from solution because of the minute size of the particles. Thus precipitation must be followed by suspended solids removal using flocculation/clarification/filtration for effective removal of inorganics.

Metals are normally precipitated from wastewaters as their hydroxides or sulfides which are less soluble. Lime or sodium sulfide/ferrous sulfide, may be used for precipitation. Often, discharge limits are either lower than the hydroxide solubilities of metals or the theoretical low sulfide solubility is not readily achieved. Therefore, proprietary chemicals and processes that employ high-efficiency suspended solids removal technologies may be employed to achieve low levels of residual concentrations. Permutit's Sulfex process, which is a ferrous sulfide-based precipitation process, and Unocal's Unipure process, which is an iron hydroxide co-precipitation process, are two commercially available proprietary technologies that can achieve low microgram/litre concentrations of metals in the effluent.

To aid in efficient suspended solids removal, coagulants/flocculants are added to form settleable solids from the precipitates. The mechanism of coagulation/flocculation involves surface chemistry and particle interactions. The surface charges on the precipitates are neutralized by coagulants, allowing the particles to approach each other. Then flocculation occurs, wherein the smaller, slowly settling particulates agglomerate with the help of the flocculants to form larger, more readily settleable particles.

Typical chemicals that are used for coagulation/flocculation are alum, lime, iron salts such as ferric chloride/ferrous sulfate, and organic water-soluble polymers such as polyacrylamides. The precipitating chemical and a coagulant/flocculant are rapidly mixed with the contaminated water in a flash mixing tank to quickly disperse the chemicals, and then are mixed in a slower and gentler fashion to allow the formation of large flocs of suspended solids.

The flocs of suspended solids are allowed to settle under the influence of gravity by maintaining quiescent hydraulic conditions in a clarifier. The water in the clarifier now contains minute concentrations of metals in the dissolved state and somewhat higher concentrations of metals in the residual suspended solids. Therefore, the clarified effluent is then filtered for further removal of suspended solids to achieve even lower concentrations of total (dissolved and suspended) metal concentrations, which are typically required under most discharge standards.

Precipitation/suspended solids removal is applicable for the removal of several heavy metals such as zinc, copper, cadmium, chromium, lead, manganese, iron, etc., and anionic species such as phosphate, sulfate, fluoride, etc. Metals such as chromium, if present in the hexavalent form, must be reduced to the less soluble trivalent form by using sulfur dioxide, ferrous salts, etc. Limitations on the effectiveness of precipitation can be posed by organic compounds that inhibit precipitation of the metals as organometallic complexes and cyanides that form highly soluble complexes with metals.

3.2.4.6   Ion Exchange

Ion exchange is a process whereby the contaminant ions are removed from the aqueous phase by exchange with relatively harmless ions (generally hydrogen ($H+$), hydroxyl ($OH-$), sodium ($Na+$), or chloride ($Cl-$)) held by the ion exchange material. Modern ion exchange resins are primarily synthetic organic materials containing ionic functional groups to which exchangeable ions are attached. These synthetic resins are structurally stable (i.e., can tolerate a range of temperature and pH conditions), exhibit a high exchange capacity, and can be tailored to show selectivity towards specific ions. Exchangers with negatively charged sites are cation exchangers because they take up positively

charged ions. Anion exchangers have positively charged sites, and consequently, take up negatively charged ions. The exchange reaction is reversible and concentration dependent, and it is possible to regenerate the exchange resins for reuse.

Ion exchange is a well established technology for removal of heavy metals and hazardous anions from dilute solutions. Ion exchange can be expected to perform well for these applications when wastes of variable composition are fed, provided the system's effluent is continually monitored to determine when resin bed exhaustion has occurred. However, the reliability of ion exchange is markedly affected by the presence of suspended solids, organics and oxidants. Suspended solids should be less than 50 mg/L to prevent plugging the resins, and waste streams must be free of oxidants. Additionally, organic concentrations should be relatively low to avoid fouling the resins. High concentrations of total dissolved solids (TDS) would reduce the effectiveness of this technology because of the nonselective nature of the removal of metal ions in normal ion exchange.

3.2.4.7 Ultrafiltration/Reverse Osmosis

Ultrafiltration is the process in which contaminated water is purified by removing colloidal particles and certain dissolved organic molecules. In this process, water is driven under pressure (up to 150 pfsi) through a porous membrane (Metcalf and Eddy, 1991). The pore size of the membrane is chosen to selectively remove the suspended and dissolved contaminants of concern. Clean water passes through the membrane for further treatment by other processes such as reverse osmosis or electrodialysis. Contaminants collect in a high-pressure compartment and must be periodically discharged. Pretreatment for the removal of gross suspended solids and for pH and temperature adjustment would be required.

Reverse osmosis is the process of removal of dissolved contaminants such as soluble organics and TDS by driving contaminants through a semipermeable membrane against the normal osmotic pressure. Under normal osmotic pressure conditions, dissolved contaminants would tend to flow through a semi-permeable membrane from a region of high concentration of the contaminants to a region of lower concentration. However, by applying a high pressure (up to 1,000 pfsi) on the clean side contaminants from the lower concentration region can be forced to migrate to the higher concentration region (Metcalf and Eddy, 1991) against the natural osmotic pressure. Ideally, it is possible to produce ultra-pure quality water in the high pressure side of the membrane. Pretreatment requirements would be more stringent than those of ultrafiltration because of the sensitivity of the semi-permeable membranes to certain physical and chemical characteristics of the contaminated water. Normally, pretreatment by ultrafiltration and removal of iron and manganese would be required for reverse osmosis.

3.2.4.8 Biological Treatment

Biological treatment of contaminated groundwater utilizes processes which have operated successfully at Publicly Owned Treatment Works (POTWs) and industrial wastewater treatment plants. Microorganisms, either suspended in the contaminated groundwater or attached to a medium, feed off the organic material, converting the more complex organics to energy for growth and cell reproduction, releasing final waste products such as carbon dioxide and water. Oxygen, and nutrients such as nitrogen and phosphorus, and micronutrients must be added to the system in order to maintain microbial growth. After a predetermined residence time has been reached, a high percentage of the biodegradable organics will have been metabolized. The microorganisms are then separated and supernatant may either be released to receiving surface waters, pumped back into the ground, or pumped to another process for additional treatment. The volume of microorganisms and other solids will continue to accumulate, with wasting of a certain amount required periodically. The waste microorganisms and solids constituting sludge will be treated by microbial digestion under oxygen-deficient conditions to form mineralized sludge prior to disposal.

Biological processes can be either aerobic or anaerobic. Aerobic operations are more common due to the fact that the microorganisms are less vulnerable to shock caused by high organic loadings or toxic inorganics than anaerobic microorganisms. For either situation, an amount of time prior to full-scale operation needs to be set aside to acclimate the microbes to the particular organics and inorganics and at the given concentrations present in the groundwater. Similarly, the pH, nutrient balance, temperature, and total residence time in the reactor will need to be adjusted in order to reach an optimal balance among these parameters.

Several chemical characteristics of the groundwater are important in assessing the effectiveness of biological treatment. Some of the most important of these chemical characteristics are the following: nature of organic contaminants; biodegradability (measured by oxygen demand for oxidation); presence of nutrients (nitrogen, phosphorus) and micronutrients (trace metals, salts, sulfur); concentration of total and suspended heavy metals; and the speciation of metals.

In general, under aerobic conditions, hydrocarbons, light petroleum distillates, and aromatic hydrocarbons (including benzene, toluene, xylene, ethylbenzene, and naphthalene) are degradable. The rate of degradation decreases with increasing molecular weight (i.e., long-chain, cyclic, and polyaromatic hydrocarbons) and decreasing solubility. Chlorinated hydrocarbons (such as DCE, TCE, and PCE) are not readily degraded aerobically. The degradation of these chemicals is more difficult with the degree of chlorine substitution. In addition, high removal efficiencies of many volatile

materials which are known to be biodegradable may be a result of volatilization instead of biodegradation. Under anaerobic conditions, chlorinated hydrocarbon compounds can be dechlorinated, but this process may create toxic byproducts such as vinyl chloride.

Metals such as arsenic, chromium, and lead can be toxic to the microorganisms, blocking enzyme reactions needed in order to metabolize the organics for energy. Inorganic particulates can be insolubilized in the water if the environment is slightly basic to neutral. Particulates are removed by sedimentation, either by attaching to the surface of a settling floc or by primary treatment prior to biological treatment.

The most common designs for biological treatment include activated sludge reactors, trickling filters, and rotating biological contactors (RBCs). These three designs are discussed in the following subsections. Anaerobic designs are not commonly in use at waste sites or industrial facilities, therefore they are not discussed below.

- Activated Sludge Reactors

   Activated sludge reactors utilize a suspended heterogeneous community of aerobic microorganisms for their metabolism of soluble and colloidal organic pollutants. Oxygen is applied either through diffusion by submerged bubblers, or through turbulent mixing. Both of these activities, aeration and mixing, keep the microbes and the pollutants suspended, allowing the organic and inorganics to be adsorbed to the microbial extra cellular layer. After a residence time of an average of a few hours, the suspension is sent to a secondary clarifier, where sedimentation of the flocculating microbes occurs. The settled solids contain the flocculated microbes, suspended inorganics, and the nonbiodegradable organics, which could not be used by the microbes as a food source. Residence time in the secondary clarifier ranges from 1 to 14 days (EPA, 1980a). The underflow from the clarifier is separated into two streams, one for recycling and the other for wasting. Recycled sludge consists of a culture of microbes which have been acclimated to the pollutants present in the groundwater. Wasted sludge is usually anaerobically digested, dewatered, and landfilled or incinerated.

- Trickling Filters

   A trickling filter is a fixed-film process consisting of a large circular basin filled with rock fragments or plastic forms that serve as filter media. A rotary arm travels over the top of the basin, spraying contaminated groundwater over the filter media. Attached to the filter

media are multiple layers of microbial cultures. These cultures adsorb organic and inorganic materials as contaminated groundwater trickles by. The system is not saturated with water; therefore, air is circulated from the bottom of the filter media to maintain aerobic conditions. Periodically, layers of the microorganisms slough off and are removed through the underdrain. This occurs either when the microbial cell mass gets too heavy to be supported, or an inner layer dies due to a lack of nutrients or oxygen. As organic solids are removed, new surface area is exposed for additional microbial growth and subsequent removal of the pollutants. The wasted microbes are clarified, then digested and removed for ultimate disposal. Limitations for this process include its unsuitability for wastewaters which have high concentrations of solids since clogging of the spray nozzles in the rotary arms is possible. Additionally, trickling filters are affected by ambient temperature, and require long acclimation times to response to changes in the influent.

● Rotating Biological Contactors (RBCs)

A RBC is a fixed-film process that consists of a series of rotating vertical discs mounted on a horizontal shaft above a trough filled with water. A microbiological slime layer forms on the discs, which are slowly rotated into and out of the trough. Pollutants are adsorbed by the slime layer, and are subsequently metabolized by the microbes. The microbes receive oxygen from exposure to the air during part of each cycle of rotation. The discs have an average diameter of 4 feet, with 40 percent submerged in the trough at any one time. During operation, flocs of biological masses will be sloughed off from the discs and will be removed by the effluent. The suspension is clarified and settled sludge is treated and disposed.

Operational parameters include the rotational speed of the discs, pre-aeration of the wastewater, and flow rate. Rotational speed and pre-aeration are controlled to ensure sufficient oxygen supply. Sufficient contact time between pollutants and microbes is controlled by regulating flow rate. Fixed-film reactors are generally expected to be more resilient to changes in organic loading and hydraulic surges. Specific advantages of RBCs include their flexibility and compactness, and the minimal amount of monitoring to operate the system. Like other biological systems, an extended start-up time is required to acclimate the microbes to the system, and shock loading of either organics or inorganics could destroy a percentage of the community, thereby affecting its ability to remove the pollutants.

In general, most ex-situ groundwater treatment technologies are affected by the following parameters: presence of organic free product; extreme pH and temperature; high levels of total suspended solids; and scale-forming agents: total dissolved solids, alkalinity, hardness, iron and manganese.

3.2.5   Offsite/Onsite Disposal

The treated water can be disposed of in three possible ways: reinjection, spray irrigation, pumping, to a local water body, or to the local wastewater treatment facility. Reinjection and spray irrigation are methods that return the groundwater into the subsurface. Disposal at the local wastewater treatment facility is a method that can be used for disposal of partially treated or untreated contaminated groundwater/surface water for further treatment. Disposal to the local water body such as a local stream or river can be considered only for the treated groundwater.

The effectiveness of reinjection and spray irrigation depends upon the hydraulic conductivity, aquifer thickness, and the hydraulic gradient/aquifer recharge rate. Spray irrigation would require adequate land surface for dispersal of the water and adequate surface infiltration rate. Climatological considerations such as severe winters can obviously affect spray irrigation. Often, these methods of disposal require treatment of the water to meet very stringent (perhaps drinking water Maximum Contaminant Levels) standards. Reinjection of the contaminated groundwater may be allowed if it is conducted as part of an in-situ remediation process, wherein extraction/reinjection is used to flush contamination in the subsurface. Such a scenario may be more readily applicable in an aquifer that is not a current or potential source of drinking water. Spray irrigation may require a minimum of VOC removal, if there is an unacceptable risk to the immediate environment and community from the VOCs emitted during spraying.

Disposal of the groundwater to a local water body would require treatment to meet surface water quality standards set by the state or the Federal ambient water quality standards. These standards may be less stringent than drinking water standards, depending on the classification of the water body.

Disposal of the groundwater or surface water to a local wastewater treatment facility can be conducted depending on the contaminants, concentrations, expected flow rates, the hydraulic design capacity of the treatment facility, etc. The treatment requirements prior to discharge would depend mainly on the available treatment operations and processes, and the NPDES permit of the wastewater treatment facility.

3.3   SUMMARY OF TECHNOLOGY SPECIFIC DATA REQUIREMENTS

As described in Sections 3.1 and 3.2, the effectiveness and implementability of soil and groundwater remediation technologies are affected by certain contaminant- and site-related physical and chemical characteristics. Tables 3-1 and 3-2 provide a summary of these concerns for each technology for soil/sediment and groundwater/surface water treatment respectively, and identifies technology-specific parameters for investigation.

TABLE 3-1

SUMMARY OF IMPLEMENTABILITY/EFFECTIVENESS CONCERNS AND IDENTIFICATION OF PARAMETERS FOR INVESTIGATION FOR WASTE/SOIL/SEDIMENT REMEDIATION
NWIRP, CALVERTON, NEW YORK

Technology	Implementability/Effectiveness Concern	Identification of Parameter for Investigation
SOILS		
Removal	• Excavation equipment limitation on depth and capacity. Type of equipment depends on type of waste. • Dredging equipment limitation on depth and capacity. Type of equipment depends on type of sediment.	• Vertical and horizontal extent of contamination. Background information on waste disposal practices. - Presence of drums, bulk debris, etc. • Vertical and horizontal extent of contamination. Physical characteristics of sediment.
INSITU TREATMENT		
Soil Washing/Solvent Extraction	• Use of appropriate solvent and achieving adequate dispersion/capture.	• Contaminant nature, geology/hydrogeology, soil organic fraction/adsorption coefficient.
Insitu Air Sparging and Vapor Extraction/Bioventing	• Limited to volatile and biodegradable contaminants. Limited by ability of air and vapors to be transported in the subsurface. Nutrients/micronutrients, pH, temperature must be suitable for survival of microbes.	• Presence of volatile organic contaminants, indication of biodegradation, etc. in the soil-gas. Air conductivity. • Biodegradability (measured by oxygen demand for oxidation), nutrients (nitrogen, phosphorus), micronutrients (trace metals, salts, sulfur).
Insitu Vitrification and Insitu Radiofrequency Heating	• Limited to unsaturated zone soils. Cannot be applied when containerized liquids/large metal objects are present.	• Depth to groundwater and rainfall potential: Background information on waste disposal practices. - Presence of drums, bulk metal debris, etc.
EXSITU TREATMENT		
Soil Washing/Solvent Extraction	• Use of appropriate solvent for removal of contaminants. • Removal effectiveness depends on adsorption to soil and achievement of liquid-solid separation as post-treatment step.	• Contaminant nature, soil type. • Soil type and organic fraction/adsorption coefficient.
Thermal Treatment	• Incinerators have limitation on combustion characteristics and inorganic contaminants. • LTTS has limitations on the type of soil and can effectively treat only volatile organics and combustible semivolatile organics.	• Heat content, presence of other contaminants, especially heavy metals. • Heat content, nature of organic contaminants.
Solidification/Stabilization	• Physical/Chemical characteristics of waste affect effectiveness. • Chemical fixation/solidification is affected by the presence of interfering agents.	• Contaminant nature, soil type, etc. • Presence of oil and grease, sulfates, soluble salts, etc.
Chemical Dechlorination	• Only effective for chlorinated organics, primarily chlorinated aromatic compounds.	• Contaminant type and concentration. • Moisture content.

TABLE 3-1
SUMMARY OF IMPLEMENTABILITY/EFFECTIVENESS CONCERNS AND IDENTIFICATION OF PARAMETERS FOR INVESTIGATION FOR WASTE/SOIL REMEDIATION
NWIRP, CALVERTON, NEW YORK
PAGE TWO

Technology	Implementability/Effectiveness Concern	Identification of Parameter for Investigation
BIOLOGICAL TREATMENT		
Landfarming	• Effective only on biodegradable contaminants.	• Nature of contaminants.
	• Less effective on clayey soils.	• Type of soil.
	• Availability of area for spreading and tilling; requirement of enclosed structure with off-gas emission treatment.	• Vacant land availability, extent of volatile organic contamination.
Bioslurry Treatment	• Effective only on biodegradable contaminants.	• Nature of contaminants.
	• Effectiveness depends on adsorption to soil and achievement of liquid-solids separation as post-treatment step.	• Type of soil, organic fraction/adsorption coefficient.
DISPOSAL		
Onsite/Offsite Landfill	• Land disposal restrictions for offsite landfilling. • Maintenance and monitoring for onsite landfilling.	• Hazardous characteristics, mainly mobility of contaminant measured by Toxicity Characteristics Leaching Procedure (TCLP). Free liquids must not be present.

TABLE 3-2

SUMMARY OF IMPLEMENTABILITY/EFFECTIVENESS CONCERNS AND IDENTIFICATION OF PARAMETERS FOR INVESTIGATION FOR GROUNDWATER REMEDIATION
NWIRP, CALVERTON, NEW YORK

Technology	Implementability/Effectiveness Concern	Identification of Parameter for Investigation
Groundwater Control/Removal	• Use of hydrodynamic controls depends on effective extraction/injection. • Use of subsurface barriers depends on site hydrogeology/geology and compatibility of wastes. • Use of extraction wells depends on depth to groundwater and site hydrology and aquifer characteristics. • Type of subsurface drain depends on hydrology; effectiveness is limited by depth, clogging due to soil particles, chemicals, etc.	• Hydrology/aquifer characteristics. • Topography, depth to confining layer, nature of soil and groundwater contaminants. • nature of contaminants, presence of floating/sinking organic free product, thickness of aquifer, recharge rates, etc. • Nature of contaminants, presence of organic free product, depth to confining layer, scaling agents, etc.
Insitu Treatment	• Effectiveness depends on achieving adequate dispersion of nutrients/oxygen and adequate capture of plume (extraction/injection). • Biological treatment is effective for biodegradable compounds. • Nutrients/micronutrients, pH and temperature must be suitable for survival of microbes.	• Hydrology/aquifer characteristics. • Nature of contaminants. • Presence of biodegradable compounds (measured by oxygen demand for oxidation), nutrients (nitrogen, phosphorus), micronutrients (trace metals, salts, sulfur), calcium and TDS.

Exsitu Treatment	• Method of nonaqueous phase liquid removed depends on type and quantity of liquid.
	
	• General limitations/interferences such as scaling/clogging of beds, coating/biofouling of membranes, etc.
	
	• Contaminant-specific limitations.
	  - Air Stripping: Volatile organic contaminant
	  - Steam Stripping: Semivolatile organic contaminants
	  - Activated Carbon Adsorption: Low solubility, least polar organic contaminants
	  - Ion Exchange: Inorganics
	  - Biological Treatment: Biodegradable contaminants
	  - Precipitation/Suspended Solids removal: Metal Oxidation state and form.
		• Floating and sinking organic free product analysis
		
		• Presence of organic free product, extreme pH and temperature, total suspended solids, total dissolved solids, alkalinity, hardness, iron and manganese.
		
		• Nature of organic contaminants; biodegradability (measured by oxygen demand for oxidation), nutrients (nitrogen, phosphorus) and micronutrients (trace metals, salts, sulfur); concentration of total and suspended heavy metals, speciation of metals.

Disposal (Offsite/Onsite)	• Disposal to surface water and for subsurface reinjection may require entensive treatment. • Disposal to local wastewater treatment facility must meet hydraulic and contaminant limitations.	• Treatment technologies and reinjection have been identified earlier. • Wastewater treatment facility operation/processes and NPDES requirements.

4.0 SITE-SPECIFIC SCREENING OF TECHNOLOGIES

This section provides a preliminary screening of technologies for soil/sediment and groundwater/ surface water remediation at the sites of concern. This screening identifies potentially applicable or not applicable technologies based on the type of contaminants. Tables 4-1 and 4-2 provide the potential corrective measure technologies for wastes/soils/sediments and groundwater/surface water, respectively, for each of the four sites.

TABLE 4-1

POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES FOR WASTES/SOILS/SEDIMENT
NWIRP, CALVERTON, NEW YORK

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7

NO ACTION

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
No Action	• No expense/implementability.	• Does not reduce mobility, toxicity, or volume of contaminants.	• Wastes • Soils • Sediments	P (wastes) P (soils) P (sediments)	P	P (soils) P (sediments)	P

CONTAINMENT

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
Containment	• Reduces migration of contaminants caused by infiltration. • Reduces migration of contaminated surface soils into sediments. • Reduces migration of contamination from sediments to surface water.	• Not a permanent remedy. • Maintenance of cap required. • Long-term liability/land use restriction.	• Wastes • Soils • Sediments	P (wastes) P (soils) P (sediments)	O	O (soils) O (sediments)	O

REMOVAL

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
Excavation	• Removes contaminated soils. • Required for exsitu technologies and disposal.	• Potential for exposure to contaminants. • Implementability concern for depth and buried containers of waste.	• Wastes • Soils	P (wastes) P (soils)	P	P	P
Dredging	• Removes contaminated sediments. • Required for exsitu technologies.	• Potential for exposure to contaminants. • Dewatering required as pretreatment for most technologies. • Treatment of contaminated water required.	• Sediment	P	N	N(1)	N

(1) Sediments at the Fuel Calibration Site are in a dry ditch.
(2) Not known if heavy metals are contaminants of concern at Fire Training Site.
P   Potentially applicable
N   No potential/less likelihood for applicability.
O   Insufficient site information to judge potential applicability.

Site 1: North-east Pond Disposal Area; Site 2: Fire Training Area; Site 6A: Fuel Calibration Area; Site 7: Fuel Depot Area.

TABLE 4-1
POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES FOR WASTES/SOILS/SEDIMENT
NWIRP, CALVERTON, NEW YORK
PAGE TWO

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7

INSITU TREATMENT

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
Insitu Soil Washing	• Excavation not required. • Most contaminants of concern are amenable to removal by extraction. • Both unsaturated and saturated zones can be remediated.	• Hydraulic permeability of subsurface is a critical criterion for effectiveness. • Petroleum hydrocarbons and pesticides may require chemical extraction. Metals may require chemical extraction or low pH water. • Adequate capture of extracted contaminants required. • Large volume of contaminated water must be treated. Disposal of concentrated wastes required. • Not well demonstrated for heterogeneous wastes such as landfill. • Containerized wastes will remain unremediated.	• Wastes • Soils	N (soils) N (wastes)	P	P	P
Insitu Air Sparging and Vacuum Extraction/ Bioventing	• Excavation not required. • Effective for VOCs. • Both unsaturated and saturated zones can be remediated. • No solvents need be injected into the subsurface. • Relatively less expensive.	• Air permeability critical. • Not effective for non biodegradable semi-VOCs, pesticides, PCBs, and metals. • Innovative technology for remediation of saturated zone. • Not demonstrated for heterogeneous wastes such as landfill. • Containerized wastes will remain unremediated. • Off-gas treatment of chlorinated organics required.	• Wastes • Soils	N (soils) N (wastes)	P	P	P
Insitu Vitrification	• No excavation required. • Residual contaminants such as metals potentially immobilized.	• Off-gas collection/treatment required. • High power consumption. • Potentially dangerous if containerized wastes are present.	• Wastes • Soils	N (soils) N (wastes)	N	N	N
Insitu Radio Frequency Heating	• No excavation required. • Low power consumption compared to most insitu technologies. • Applicable to most organic contaminants.	• Not applicable to inorganic contaminants. • Off-gas collection/treatment required. • Potentially dangerous if containerized wastes are present. • Not well demonstrated for heterogeneous wastes.	• Wastes • Soils	N (soils) N (wastes)	O(2)	P	N

TABLE 4-1
POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES FOR WASTES/SOILS/SEDIMENT
NWIRP, CALVERTON, NEW YORK
PAGE THREE

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7

EXSITU TREATMENT

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
Soil Washing/Solvent Extraction	• Most contaminants of concern are amenable to removal by extraction. • Minimal concern for dispersion of solvents in the environment.	• Soil type is important for effectiveness. • Excavation of soils required. • Dredging of sediments required, partial dewatering may be required. • Treatment of extracted contaminants/disposal of concentrated wastes required.	• Wastes • Soils • Sediments	P (wastes) P (soils) P (sediments)	P	P (soils) P (sediments)	P
Thermal Treatment • Low Temperature Thermal Treatment	• Removal of VOCs and some semi-VOCs and destruction of combustible compounds. • Soil type is important for throughput but not critical for effectiveness.	• Excavation of soils and dredging/dewatering of sediments required. • Effectiveness limited for consolidated (clayey) soils. • Not applicable to removal of metals. • Off-gas emissions treatment and scrubber wastes treatment required for most equipment. • Containerized wastes may not be readily treated.	• Wastes • Soils • Sediments	N (wastes) N (soils) N (sediments)	P	P (soils) P (sediments)(1)	P
• Incineration	• Destruction of all organics and volatilization of some metals. • Soil type is not very important criterion for throughput or effectiveness. • Containerized wastes may be treated.	• Excavation of soils and dredging/dewatering of sediments required. • Onsite mobile incinerators require permitting. • Off-gas emission treatment and scrubber water treatment required. • Ash disposal as a potentially hazardous waste required, if heavy metal concentrations are significant. • Relatively more expensive.	• Wastes • Soils • Sediments	N (wastes) N (soils) N (sediments)	P	P (soils) P (sediments)(1)	P

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7

EXSITU TREATMENT (Continued)

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
Solidification/ Stabilization • Chemical Fixation/ Solidification	• Can effectively reduce mobility of inorganics. • Minimal byproducts of treatment.	• Excavation of soils and dredging of sediments required. Partial dewatering of sediments required. • Not well demonstrated for heterogeneous wastes; containerized wastes in landfill will be remediated. • Not applicable if primary contaminants are organics. • Increases total volume of waste for disposal. • Long-term effectiveness on reduction of mobility of contaminants unknown.	• Wastes • Soils • Sediments	P (wastes) P (soils) P (sediments)	N	N (soils) N (sediments)	N (soils)
• Encapsulation	• Can reduce mobility of organics and inorganics. • Little byproduct of treatment, if any. • Jacketing is readily applicable technology for containerized wastes and other heterogeneous wastes.	• Excavation of soils and dredging of sediments required. • Long-term integrity of encapsulating material questionable. • Does not reduce toxicity, or volume of contaminants. Long-term reduction of mobility of contaminants questionable.	• Wastes • Soils • Sediments	P (wastes) P (soils) P (sediments)	P	P (soils) P (sediments)	P (soils)
Biological Treatment • Landfarming	• Effective for treatment of petroleum hydrocarbons. • Minimal residuals of treatment. • Relatively low volumes of byproducts of treatment. • Potentially one of the least expensive of technologies.	• Excavation of soils is required; dredging and dewatering of sediments required. • Not applicable for removal of nonbiodegradable semi-VOCs, pesticides and heavy metals. • Soil type may pose some difficulty in implementation. • Large area of relatively even land required. • Enclosed structure required if ambient temperature is unsuitable. • Enclosed structure required if off-gas emissions are significant.	• Wastes • Soils • Sediments	N (wastes) N (soils) N (sediments)	P	P (soils) P (sediments)	P

TABLE 4-1
POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES FOR WASTES/SOILS/SEDIMENT
NWIRP, CALVERTON, NEW YORK
PAGE FIVE

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7

EXSITU TREATMENT (Continued)

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
• Bioslurry Treatment	• Effective for treatment of petroleum hydrocarbons and potentially other organic contaminants. • Relatively less expensive.	• Excavation of soils required; dredging and partial dewatering of sediments required. • Removal of nonbiodegradable semi-VOCs, pesticides, and heavy metals require post treatment. • Off-gas emission treatment required if chlorinated VOC concentrations are significant.	• Wastes • Soils • Sediments	N (wastes) N (soils) N (sediments)	P	P (soils) P (sediments)	P
Chemical Treatment • Chemical Dechlorination	• Effective if only halogenated compounds are present at a site.	• Specific to halogenated compounds only; primarily halogenated aromatic compounds.	• Wastes • Soils • Sediments	N (wastes) N (soils) N (sediments)	P(2)	N (soils) N (sediments)	N
Disposal (Onsite/Offsite) Landfill	• Effective method of disposal of treated soils/sediments.	• Long-term liability of disposal of untreated wastes questionable. • No reduction in toxicity, mobility, or volume of wastes can occur. • Onsite disposal requires permitting and extensive long-term monitoring and maintenance. • High Cost.	• Wastes • Soils • Sediments	P (wastes) P (soils) P (sediments)	P	P (soils) P (sediments)	P

(1)   Sediments at the Fuel Calibration Site are in a dry ditch.
(2)   Not known if heavy metals are contaminants of concern at Fire Training Site.
P   Potentially applicable
N   No potential/less likelihood for applicability.
O   Insufficient site information to judge potential applicability.

Site 1: North-east Pond Disposal Area; Site 2: Fire Training Area; Site 6A: Fuel Calibration Area; Site 7: Fuel Depot Area.

TABLE 4-2

POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES FOR GROUNDWATER/SURFACE WATER
NWIRP, CALVERTON, NEW YORK

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7
NO ACTION							
No action	• No expense/implementability	• Does not reduce mobility, toxicity, or volume of contaminants • May not be protective of human health and the environment	• Groundwater • Surface water	P	P	P	P
GROUNDWATER CONTROL/EXTRACTION							
Hydrodynamic (Pumping/Subsurface Drains)	• Proven technology for plume containment or for contaminant removal.	• Generates contaminated water for treatment and/or disposal. • Effectiveness highly dependent on geology and hydrogeology.	• Groundwater • Surface Water	P	P	P	P
Passive Containment (Subsurface Barriers)	• Reduces migration of shallow subsurface contaminant plume.	• No reduction in toxicity, or volume of contamination. • Effectiveness dependent on availability of aquifer-confining layer of high integrity. • Long-term effects of contaminants on structural integrity of barriers is questionable.	• Groundwater	P	P	P	P
REMEDIAL TECHNOLOGIES: INSITU TREATMENT							
Air Sparging	• Groundwater extraction not required. • Potentially rapid removal of VOC contaminants. • Relatively less expensive.	• Not proven; not well documented. • Not effective for heavy metals or nonbiodegradable semi-VOCs (pesticides/PCBs). • Effectiveness dependent on local geology and hydrogeology. • Off-gas emission treatment required.	• Groundwater	N	P	P(1)	P(1)
Biological Treatment	• Potentially minimal byproducts requiring further treatment. • Effective for degradation of petroleum hydrocarbons. • Relatively less expensive.	• Effectiveness for complete degradation; chlorinated aliphatics not well demonstrated. • Groundwater extraction and reinjection required. • Effectiveness highly dependent on local geology and hydrogeology. • Removal of metals and nonbiodegradable organics (PCBs/pesticides) requires above-ground treatment.	• Groundwater	N	N	N	P

(1) Not known if lead contamination is of concern.

P   Potentially applicable
N   Not potentially applicable.
O   Insufficient site information to judge potential applicability.

Site 1: North-east Pond Disposal Area; Site 2: Fire Training Area; Site 6A: Fuel Calibration Area; Site 7: Fuel Depot Area.

TABLE 4-2
POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES FOR GROUNDWATER/SURFACE WATER
NWIRP, CALVERTON, NEW YORK
PAGE TWO

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7

REMEDIAL TECHNOLOGIES: EXSITU TREATMENT

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
Nonaqueous-Phase Liquid (NAPL) Removal	• Effective for removal of floating organic free product. • Required as pretreatment for pump-and-treat technologies.	• Effectiveness not well demonstrated for insitu NAPL removal. • Organic product must be disposed of off site.	• Nonaqueous-phase liquid	N	P	P	P
Air/Steam Stripping	• Effective for removal of organics; well demonstrated. • Low levels of residual concentrations achievable.	• Extraction of groundwater required. • Contaminants are transferred to another medium that would require further treatment. • Pretreatment for removal of TSS, scaling agents, organic free product required. • Air stripper effluent requires post-treatment for removal of semi-VOCs.	• Groundwater • Surface Water	N	P	P	P
Activated Carbon Adsorption	• Effective for removal of most organics; well demonstrated. • Typically low levels of residual concentrations achievable. • Some removal of metals achievable (polishing stage).	• Extraction of groundwater required. • Spent activated carbon must be regenerated/disposed. • Pretreatment for removal of TSS, scaling agents, organic free product required. • Very high consumption expected for certain organics.	• Groundwater • Surface Water	N	P	P	P
Enhanced Oxidation	• Potentially effective for destruction of most organics. • Low levels of residual concentration expected. • Minimal byproducts of treatment.	• Groundwater extraction required. • Not well demonstrated. • Process sensitive to interfering agents: TSS, scaling agents, organic free product, iron, manganese, etc. • Extensive pretreatment may be necessary to Calverton sites because of high iron concentrations. • Typically expensive operation. • No removal of metals expected.	• Groundwater • Surface Water	N	P	P	P

TABLE 4-2
POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES FOR GROUNDWATER/SURFACE WATER
NWIRP, CALVERTON, NEW YORK
PAGE THREE

Technology	Advantages	Disadvantages	Media	Sites for Potential Use			
				Site 1	Site 2	Site 6A	Site 7

REMEDIAL TECHNOLOGIES: EXSITU TREATMENT (Continued)

Technology	Advantages	Disadvantages	Media	Site 1	Site 2	Site 6A	Site 7
Precipitation/Suspended Solids Removal	• Proven technology for removal of suspended solids/metals (dissolved/suspended). • Typically required as pretreatment for pump-and-treat technologies.	• Groundwater extraction required. • Sludge disposal required. • Increase in TDS of water inevitable for pH adjustment/precipitation.	• Groundwater • Surface Water	P	P	P	P
Ion Exchange	• Proven technology for removal of dissolved metals. • Typically low levels of residual concentrations achievable. • Specialized resins available for selective removal of target heavy metals and certain organics.	• Groundwater extraction required. • Regenerant disposal required. • Nonselective in removal of contaminants; consequently expensive. • Pretreatment for removal of TSS, scaling agents, and organic free product required. • Effluent monitoring important.	• Groundwater • Surface Water	P	P	O[1]	O[1]
Reverse Osmosis/ Ultrafiltration	• Effective for removal of dissolved contaminants.	• Groundwater extraction required. • Concentrated contaminants require disposal. • High power consumption. • Pretreatment for removal of scaling agents, iron, manganese, etc., required. • Membrane is typically maintenance intensive.	• Groundwater • Surface Water	P	P	P	P
Biological Treatment • Activated Sludge • Tracking Filters • Rotating Biological Contactors	• Effective for removal of petroleum hydrocarbons. • Typically low expense.	• Not well demonstrated for removal of chlorinated aliphatics. • Minimal removal of metals expected. • Long periods of acclimation required. • Off-gas emission treatment required. • Post-treatment required for removal of PCBs/pesticides.	• Groundwater • Surface Water	N	N	N	P

5.0 GENERAL IDENTIFICATION OF DATA REQUIREMENTS

Section 3.3 identified technology-specific data requirements for an evaluation of the effectiveness of a corrective measure technology or to address implementability concerns. Section 4.0 presented a preliminary screening of potentially applicable technologies to each of the four sites. In this section, the technology-specific data requirements are stated pertaining to potentially applicable technologies for each of the four sites. Table 5-1 provides a summary of contaminants and identifies additional data requirements pertaining to risk and technologies for soils/sediments and groundwater/surface water, respectively, at each site.

TABLE 5-1

GENERAL IDENTIFICATION OF DATA REQUIREMENTS
NWIRP, CALVERTON, NEW YORK

Constituents Associated with Unit		Objective	Additional Data Required		
Historical Waste Disposal Practices	Past Studies[1]		Release Verification/ Contaminant Distribution	Risk	Engineering

SITE 1 - NORTHEAST POND DISPOSAL AREA

• Petroleum Oils and Lubricants
 	
• Asphalt Paving Material
 	
• Halogenated and Nonhalogenated Solvents
 	
• Paint Sludges
 	
• Bulk Disposal of Debris: building and office material, aircraft sections and tooling machinery, pallets and paint cans
	• Soil/Waste contamination
	  - Unsaturated zone
	    (1) PAHs, phthalates, PCBs
	    (2) Inorganics (arsenic, barium, cadmium, chromium, copper, lead, mercury, and nickel)
	
	  - Capillary/Saturated zone Similar contaminants but lower frequency of detection
	
	• Groundwater not investigated
	
	• Surface water
	  - Heavy metals: aluminum, chromium, lead, zinc and cyanide above AWQCs
	
	• Sediments
	  - Heavy metals: chromium, copper and zinc detected.
		Define nature and extent of soil, waste, surface water, sediment, and potential groundwater contamination.	• Source of contamination expected to be disposal area.
			
			• Waste/soil/sediment chemical characteristics
			  - TCL volatiles
			  - TCL semivolatiles
			  - PCB/pesticides
			  - TAL inorganics
			
			• Groundwater/surface water chemical characteristics
			  - TCL volatiles
			  - TCL semivolatiles
			  - PCB/pesticides
			  - TAL inorganics
				• Human health and environmental risk due to contaminants in disposal area
				  - Direct contact
				  - Inhalation
				  - Erosion/migration to pond water and sediments
				
				• Environmental risk due to contaminants in pond
				  - Surface water
				  - Sediments
				
				• Potential for migration to groundwater.
					• Soil/sediment physical characteristics
					  - Particle size analysis
					  - Density, moisture content
					
					• Soil chemical characteristics
					  - TOC, TPH
					  - BTU of bulk material
					  - TCLP/characteristic
					
					• Sediment chemical characteristics
					  - TOC, TPH
					
					• Groundwater/surface water quality data
					  - Temperature and pH
					  - TSS, TDS
					  - Alkalinity, hardness
					  - TOC, BOD, COD
					  - Hexavalent/chromium
					  - Hydraulic conductivity

[1] Site Investigation Halliburton NUS.

Legend for abbreviations:

AWQC:	Ambient Water Quality Criteria		TAL:	Target Analyte List
BTU:	British Thermal Unit (measure of heat content)		TCL:	Target Compound List
BOD:	Biochemical Oxygen Demand		TCLP:	Toxicity Characteristic Leaching Procedure
COD:	Chemical Oxygen Demand		TDS:	Total Dissolved Solids
DNAPL:	Dense Nonaqueous Phase Liquid (Sinking Free Product)		TOC:	Total Organic Carbon
LNAPL:	Light Nonaqueous Phase Liquid (Floating Free Product)		TPH:	Total Petroleum Hydrocarbon
PAH:	Polynucleated Aromatic Hydrocarbons		TSS:	Total Suspended Solids
PCBs:	Polychlorinated Biphenyls		VOC:	Volatile Organic Contaminant

TABLE 5-1
GENERAL IDENTIFICATION OF DATA REQUIREMENTS
NWIRP, CALVERTON, NEW YORK
PAGE TWO

Constituents Associated with Unit		Objective	Additional Data Required		
Historical Waste Disposal Practices	Past Studies[1]		Release Verification/ Contaminant Distribution	Risk	Engineering
SITE 2 - FIRE TRAINING AREA					

• Waste Heating Fuels
 	
• Diesel Fuel
 	
• Jet Fuels (JP-4, JP-5)
 	
• Waste Solvents (toluene, methyl ethyl ketone, lacquer thinner)
	• Soil contamination
	  - Unsaturated zone
	   (1) Nonchlorinated aromatics (fuel-related)
	   (2) Semi-VOCs (naphthalene, phthalates, PAHs)
	   (3) Lead was also detected
	
	  - Capillary/saturated zone
	   (1) Chlorinated aliphatics (solvent-related)
	   (2) Nonchlorinated aromatics (fuel-related)
	   (3) Semi-VOCs (naphthalene, phthalates, PAHs)
	   (4) Pesticides
	
	• Groundwater contamination
	  - Nonchlorinated aromatics (fuel-related)
	  - Chlorinated aliphatics (solvent-related)
	  - Semi-VOCs (phenols, phthalates, PAHs)
	  - Inorganics (heavy metals, cyanide)
	  - Pesticides were also detected
	  - Floating free product
		Define nature and extent of soil and groundwater contamination	• Obtain surface and subsurface soil samples around underground storage tank, above-ground storage tank and fire training pit
			
			• Sample groundwater
			
			• Soil/sediment chemical characteristics
			  - TCL volatiles
			  - TCL semivolatiles
			  - PCB/pesticides
			  - TAL inorganics
			
			• Groundwater/surface water chemical characteristics
			  - TCL volatiles
			  - TCL semivolatiles
			  - PCB/pesticides
			  - TAL inorganics
				• Human health and environmental risk due to surface soils
				  - Direct contact
				  - Inhalation
				
				• Potential for migration of groundwater contaminants
					• Soil physical characteristics
					  - Particle size analysis
					  - Bulk density, moisture content
					  - Water and air permeability, porosity
					
					• Soil chemical characteristics
					  - TOC, TPH
					  - BTU
					  - Soil gas/headspace
					  - TCLP/characteristic wastes
					  - Organic lead
					
					• Groundwater quality
					  - Temperature and pH
					  - TSS, TDS
					  - Alkalinity, hardness
					  - TOC, BOD, COD, TPH
					  - Organic lead
					  - Hydraulic conductivity
					
					• LNAPL and DNAPL
					  - BTU
					  - Organic lead
					  - PCB/pesticides

TABLE 5-1
GENERAL IDENTIFICATION OF DATA REQUIREMENTS
NWIRP, CALVERTON, NEW YORK
PAGE THREE

Constituents Associated with Unit		Objective	Additional Data Required		
Historical Waste Disposal Practices	Past Studies[1]		Release Verification/ Contaminant Distribution	Risk	Engineering

SITE 6A - FUEL CALIBRATION AREA

• Jet Fuel Spills (JP-4, JP-5)	• Soil contamination
	  - Unsaturated zone
	    (1) Chlorinated aliphatics (solvent-type)
	    (2) Nonchlorinated aromatics (fuel-related)
	    (3) Semi-VOCs (naphthalene, PAHs) and lead were also detected
	
	  - Capillary/saturated zone Contaminant concentrations were below background levels
	
	• Groundwater contamination
	  - Chlorinated aliphatics (solvent-type)
	  - Nonchlorinated aromatics (fuel-related) and chlorobenzene
	  - Semi-VOCs (PAHs, phthalates)
	  - Lead
		Define nature and extent of soil, sediment, and groundwater contamination	• Soil samples around fuel calibration pad.
			
			• Soil samples around fuel piping.
			
			• Soil chemical characteristics
			  - TCL volatiles
			  - TCL semivolatiles
			  - Lead
			
			• Groundwater chemical characteristics
			  - TCL volatiles
			  - TCL semivolatiles
			  - Lead
				• Human health and environmental risk due to contaminants in surface soils
				  - Direct contact
				  - Inhalation
				
				• Potential for migration of groundwater contaminants
					• Soil physical characteristics
					  - Particle size analysis
					  - Bulk density, moisture content
					  - Air and water permeability, porosity
					
					• Soil chemical characteristics
					  - TOC, TPH, BOD, COD
					  - BTU
					  - Soil-gas headspace
					  - TCLP/characteristic wastes
					  - Organic lead
					
					• Groundwater quality
					  - Temperature and pH
					  - TSS, TDS
					  - Alkalinity, hardness
					  - TOC, BOD, COD, TPH
					  - Organic lead
					  - Hydraulic conductivity
					
					• LNAPL and DNAPL
					  - BTU
					  - Organic lead
					  - PCBs/pesticides

TABLE 5-1
GENERAL IDENTIFICATION OF DATA REQUIREMENTS
NWIRP, CALVERTON, NEW YORK
PAGE FOUR

Constituents Associated with Unit		Objective	Additional Data Required		
Historical Waste Disposal Practices	Past Studies[1]		Release Verification/ Contaminant Distribution	Risk	Engineering

SITE 7 - FUEL DEPOT

• Leaks and Spills from Fuel Storage and Dispensation (jet fuel: JP-4, JP-5)	• Soil contamination - Unsaturated zone (1) One detection of 1,2-DCA at 1 µg/kg (2) Two detections of PAHs at 322 µg/kg and 4,750 µg/kg each - Capillary/saturated zone (1) One detection of 1,2-DCA at 5 µg/kg • Groundwater contamination - Nonchlorinated aromatics (fuel-related) - Semi-VOCs (PAHs and phthalates) - Lead - 1,1,1-TCA was detected at 1 µg/kg	Define nature and extent of soil and groundwater contamination	• Soil samples around underground storage tanks • Soil samples around pumphouse and truck fill stand • Soil chemical characteristics - TCL volatiles - TCL semivolatiles - Lead • Groundwater chemical characteristics - TCL volatiles - TCL semivolatiles - Lead	• Human health and environ-mental risk due to surface soil contamination - Direct contact - Inhalation • Potential for migration of groundwater contaminants	• Soil physical characteristics - Particle size analysis - Bulk density, moisture content - Air and water permeability, porosity • Soil chemical characteristics - TOC, TPH, BOD, COD - BTU - Soil-gas/headspace analysis - TCLP/characteristic - Organic lead • Groundwater quality - Temperature and pH - TSS, TDS - Alkalinity, hardness - TOC, BOD, COD, TPH - Metals (total and dissolved) - Organic lead - hydraulic conductivity • LNAPL and DNAPL - BTU - Organic lead - PCB/pesticides

(1) Site Investigation Halliburton NUS.

Legend for abbreviations:

AWQC:	Ambient Water Quality Criteria		TAL:	Target Analyte List
BTU:	British Thermal Unit (measure of heat content)		TCL:	Target Compound List
BOD:	Biochemical Oxygen Demand		TCLP:	Toxicity Characteristic Leaching Procedure
COD:	Chemical Oxygen Demand		TDS:	Total Dissolved Solids
DNAPL:	Dense Nonaqueous Phase Liquid (Sinking Free Product)		TOC:	Total Organic Carbon
LNAPL:	Light Nonaqueous Phase Liquid (Floating Free Product)		TPH:	Total Petroleum Hydrocarbon
PAH:	Polynucleated Aromatic Hydrocarbons		TSS:	Total Suspended Solids
PCBs:	Polychlorinated Biphenyls		VOC:	Volatile Organic Contaminant

REFERENCES

Ackerman, D. G., et al., 1983. <u>Destruction and Disposal of PCBs by Thermal and Non-Thermal Methods</u>. Noyes, Park Ridge, New Jersey.

Arienti, M., et al., 1986. <u>Technical Resource Document: Treatment Technologies for Dioxin-Containing Wastes</u>. U.S. EPA HWERL, Contract No. 68-3-3243 (from EPA/600/2-87/098).

Atlas, R. M., 1981, "Microbial Degradation of Petroleum Hydrocarbons: An Environmental Perspective." Microbiological Reviews, 45 (1): 180-209.

Bartha, R. and Bossert, I., 1981 "The Treatment and Disposal of Petroleum Wastes" Petroleum Microbiology, McMillan Publishing Company, New York.

Bernardin, F. E. and E. M., Froelich, 1990. "Chemical Oxidation of Dissolved Organics Using Ultraviolet-Catalyzed Hydrogen Peroxide," Superfund, pp. 768-771.

Bossert, I., and Bartha, R., 1984. "The Fate of Petroleum in the Soil Ecosystem." In: Petroleum Microbiology, R. M. Atlas, editor. MacMillan Publishing Company, New York.

Bouwer, E. J., and P. L. McCarty, 1981. "Transport of Halogenated Organic Components Under Denitrification Conditions," <u>Applied and Environmental Microbiology</u>, 45(4),pp. 1295-1299.

Brenner, W., and B. Rugg, 1982. "Exploratory Studies on the Encapsulation of Selected Hazardous Wastes with Sulfur-Asphalt Blends," <u>Land Disposal of Hazardous Waste: Proceedings</u>.

Brenton, M. A., et al., 1986. <u>Technical Resource Document: Treatment Technologies for Solvent-Containing Wastes</u>. U.S. EPA HWERL, Contract No. 68-3-3243. (From EPA/600/2-87/098).

Brunner, C. R., 1984. <u>Incineration Systems</u>. Van Nostrand Reinhold Company, New York, New York.

Camp, Dresser & McKee Inc., 1985a. <u>Alternative Treatment Technologies for Superfund Waste</u>, prepared for the U.S. Environmental Protection Agency under Contract No. 68-01-7053, September.

Camp Dresser & McKee, Inc., 1985b. Alternative Technologies for Treatment and Disposal of Soils Contaminated with Organic Solvents, prepared for U.S. EPA under Contract No. 68-01-7053, October.

Cosmos, Mike, 1992. Personal Communication between M. Cosmos, Weston Services, Inc., and D. Cohen, HALLIBURTON NUS, April 30, 1992 and May 7, 1992.

Ellis, W. D., T. R. Fogg, and A. N. Tafuri, 1978. "Treatment of Soils Contaminated with Heavy Metals." In Proceedings of the 1978 National Conference on Control of Hazardous Material Spills, Miami Beach, Florida.

Engleman, V. S. and D. L. DeLes, 1983. "Incineration Technology for Selecting Small Quantity Hazardous Waste Generators." In Incineration and Treatment of Hazardous Wastes: Proceedings of the Eighth Annual Research Symposium, Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, pp. 56-62. Environmental Solutions, Inc. Brochure. Baton Rouge, Louisiana.

EPA (U.S. Environmental Protection Agency), 1977. Environmental Protection Technology Series - Development of a Polymeric Cementing and Encapsulating Process for Managing Hazardous Wastes prepared for the U.S. Environmental Protection Agency by TRW Systems Group. EPA-600/2-77-045.

EPA, 1980. Hazardous Waste Management System. 4SFR 330066. Codified 40 CFR 260, 261, etc.

EPA, 1982. Guide to the Disposal of Chemically Stabilized and Solidified Waste. SW-872, Municipal Environmental Research Laboratory, Cincinnati, Ohio, September.

EPA, 1984a. Review of In-Place Treatment Techniques for Contaminated Surface Soils. Volume 1 (Technical Evaluation). EPA/540/2-84-003a, by A. D. Little for HWERL, Cincinnati, Ohio, September.

EPA, 1985, "Remedial Action at Waste Disposal Sites," EPA/625/6-85/006.

EPA, 1985a. "Project Summary - Treatment of Contaminated Soils with Aqueous Surfactants." EPA/600/S2-85/129, HWERL, Cincinnati, Ohio, October.

EPA, 1986a. Mobile Treatment Technologies for Superfund Wastes. EPA 540/2-86/003(f), Office of Solid Waste and Emergency Response, Washington, D.C., September.

EPA, 1987. Technologies for Halogenated Organic Containing Wastes, EPA/600/2-87/098, Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio. EPA, 1987-see pg. 3-27.

EPA, 1988. Technology Screening Guide for Treatment of CERCLA Soil and Sludges. EPA/540/2-88/004.

EPA, March 1990. "Assessing UST Corrective Action Technologies: Site Assessment and Selection of Unsaturated Zone Treatment Technologies," EPA/600/2-90/011, March 1990.

EPA, June 1990. "Assessing UST Corrective Action Technologies: Early Screening of Cleanup Technologies for the Saturated Zone," EPA/600/2-90/027, June 1990.

Erdogan, H., and M. M. Sadat, 1984. "Soil Detoxification Methods: State-of-the-Art Review." In Toxic and Hazardous Wastes: Proceedings of the 16th Mid-Atlantic Industrial Waste Conference, p. 472-486.

Fitzpatrick, V. F. et al., 1984. "In-situ Vitrification: A Potential Remedial Action Technique for Hazardous Waste Sites." In The Fifth National Conference on Management of Uncontrolled Hazardous Waste Sites. Hazardous Materials Control Research Institute, Silver Spring, Maryland, pp. 191-194.

Freeman, H. M. and R. A. Olexsey, 1986. "A Review of Treatment Alternatives for Dioxin Wastes." In Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste: Proceedings of the Twelfth Annual Research Symposium. EPA/600/9-86-022, Hazardous Waste Engineering Research Laboratory, EPA, Cincinnati, Ohio, pp. 285-297.

Glynn, W. K. and E. P. Kunce, 1986. "Mobile Treatment Technologies." pp. 345-349.

HALLIBURTON NUS, 1992. Final Site Investigation, Naval Weapons Industrial Reserve Plant, Calverton, New York, Vol. I, April.

Hutzler, N. J., Murphy, B. E., Gierke, J. S., "State of Technology Review Soil Vapor Extraction Systems" HWERL, EPA 600/2-89-024, 1989.

IIT, IIT Research Institute ,1988. "Radio Frequency In Situ Heating." The Hazardous Waste Consultant, May/June.

Johanson, J. G., et al., 1983. "Elimination of Hazardous Wastes by the Molten Salt Destruction Process." In Incineration and Treatment of Hazardous Wastes: Proceedings of the Eighth Annual Research Symposium, Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, pp. 234-242.

Kieng, Y., et al., 1982. Hazardous Waste Processing Technology, Ann Arbor Science, Boston.

Lee, M.D., Thomas, J.M., Borden, R.C., Bedient, P.B., Wilson, J.T., Ward, C.H., "Biorestoration of Aquifers Contaminated with Organic Compounds," National Center for Groundwater Research, CRC Critical Reviews in Environmental Control, Vol. 18, Issue 1, 1988, pp. 29-89.

A. D. Little, Inc., September, 1986. Innovative Technology Development for Rocky Mountain Arsenal. Prepared for U.S. Army Toxic and Hazardous Materials Agency.

Loynachan, T. E., 1978. "Low-Temperature Mineralization of Crude Oil in Soil." Journal of Environmental Quality, Volume 7, No. 4, pp. 494-500.

Lubowitz, H.R., and C.C. Wiles, 1981. "Management of Hazardous Waste by Unique Encapsulation Process" - Land Disposal: Hazardous Waste Proceedings of the Seventh Annual Research Symposium held in Philadelphia, Pennsylvania. U.S. EPA NTIS No. PB821-173022.

Madison, E. L., 1991. "Determining in situ Biodegradation," Environmental Science Technology, Volume 25, No. 10.

Marley, M. C., Hazebrouck, D. J., Walsh, M. T., "The Application of In Situ Air Sparging as an Innovative Soils and Groundwater Remediation Technology," GWMR, Spring 1992, pp. 137-145.

McShea, L. J., M. D. Miller, and J. R. Smith, 1987. "Combining UV/Ozone to Oxidize Toxics," Pollution Engineering, Volume 19, No. 3, pp. 58-59.

Metcalf and Eddy, 1991, "Wastewater Engineering Treatment Disposal Reuse" 3rd edition, 1991.

Nash, J., and R. P. Traver, 1986. "Field Evaluation of In-Situ Washing of Contaminated Soils with Water/ Surfactants." In Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Wastes: Proceedings of the Twelfth Annual Research Symposium.

Nelson, M. J., J. V. Kinsella, and T. Montoya, 1990. "Insitu Biodegradation of TCE Contaminated Groundwater," Environmental Progress, Volume 9, pp. 190-196.

Nielson, Roger K., Michael G. Cosmos, 1989. "Low Temperature Thermal Treatment (LT3) of Volatile Organic Compounds From Soil: A Technology Demonstrated", Environmental Progress, Volume 8, No. 2, pp. 139-142.

Peterson, R. L., 1986. "Method for Decontaminating Soil." U.S. Patent Number 4,574,013 assigned to Galson Research Corporation, East Syracuse, New York.

RGH (Rogers, Golden, and Halpein), 1986. Initial Assessment Study of NWIRP Bethpage, New York, and NWIRP Calverton, New York. Contract No. 62474-84-3386, Environmental Restoration Department, Naval Energy and Environmental Support Activity, December.

Rulkens, W. H., J. W. Assink, and W. J. VanGemert, 1985. "On-Site Processing of Contaminated Soil." In Contaminated Land--Reclamation and Treatment, M. A. Smith, ed., Plenum Press, New York, pp. 37-90.

Smith, M. A., ed., 1985. Contaminated Land - Reclamation and Treatment, Plenium Press, New York.

Swanstrom, Carl, 1991. "Determining the Applicability of X*TRAX for On-site Remediation of Soil Contaminated with Organic Compounds," Chemical Waste Management, Inc., Technical Note 91-143.

Swanstrom, Carl, and Carl Palmer, 1991. "Thermal Separation of Solids Contaminated with Organics," Chemical Waste Management, Inc., Technical Note 91-213.

Truett, J. B., R. L. Holberger, and D. E. Sanning, 1982. "In-situ Treatment of Uncontrolled Hazardous Waste Sites." In The Fifth National Conference on Management of Uncontrolled Hazardous Waste Sites. Hazardous Materials Control Research Institute, Silver Spring, Maryland, pp. 451-457.

U.S.G.S., 1967. Topographic Map 7.5 Minute Series Quadrangles - Wading River, New York, 1967; Riverhead, New York, 1967; Moriches, New York, 1967; Eastport, New York, 1956; Bellport, New York, 1967; and Middle Island, New York, 1967.